KDS Micronex Machine

The KDS Micronex is a type of grinder, which has the beneficial and originally unintended serendipitous side-effect of drying anything that it grinds. No supplementary heat input is required, yet it has been demonstrated to dry, for example, de-inking (paper) sludge from an initial moisture content of 54 % (on a wet basis) to a final moisture content of 12 % , while grinding it to reduce its particle size. It also has been found to destroy the pathogens that may be found in the material being ground.

The attached schematic diagram shows the KDS Micronex machine and the isometric sectional view of the torus. The KDS chamber, whose diameter is 1.3 m, encloses a set of 8 spinning chains and a stationary torus above it. The chains are spun around in a horizontal plane by a motor-driven hub. The velocity at the chain tips is 200 m/s, so there is significant frictional heating of the surrounding air due to the aerodynamic drag of the chains, i.e., "paddle work". The top of the torus is concave and its bottom is flat. Eight radially disposed baffle plates are welded at 120^0 to the bottom surface of the torus. The blades provide a surface for the particles to impinge on, causing them to shatter. In addition, the blades direct the peripheral air to flow through the central hole of the torus.

The raw material is fed into the KDS chamber through the inlet star valve. It slides down the concave sides of the torus and falls on top of the spinning hub. Size reduction or grinding occurs because three different forces act on the material:

1. An average centripetal acceleration of 4600 gees flings the material (and some air) against the sides of the KDS chamber. The impact pulverizes the material. Some comminution also occurs because the centripetal force literally pulls the material apart.
2. Since the particles are accelerated along a radial path while also moving in a circular path due to the air movement caused by the chains, the Coriolis force also plays a part in the break-up of the material.
3. The particles also collide against the baffle plates and the chains and with each other and get comminuted.

The drying of the raw material happens simultaneously with the grinding process, due to the following mechanisms:

1. The immense centrifugal force peels away any water layer on the outer surface of the material. As the grinding proceeds, new surface is constantly being created and any newly exposed layer of water on the material surface also gets sheared away. This drying mechanism relies on mechanical forces to dewater the material.
2. Another mechanism of drying is semi- thermal in nature. The kinetic energy of multiple impacts briefly heats particles undergoing such impacts to beyond 100 ^{0}C, so the moisture in them is flashed into steam. The steam escapes from the particles and then immediately re-condenses into a fine mist, since the temperatures inside KDS Micronex machine never exceed 90^0C. Some water is also expelled because the forces of impact literally squeeze the water out of the particles. Thus, the particles lose their water content without requiring external heating, because water removal is partly due to mechanical forces.
3. Air temperatures inside the chamber can be between 70 and 90 ^{0}C, because the supplied shaft power ultimately degrades into heat during the grinding process, and also because of aerodynamic heating. The very high heat and mass transfer co-efficients due to the extreme velocities ensure near-instantaneous transport of moisture between the particles and the surrounding air. The large combined surface area of the particles also facilitates very high heat and mass transfer rates. This drying mechanism is a purely thermal one.

The direction of air movement in the KDS chamber is indicated by arrows. The air flow caused by the chains doubles back on itself and goes out through the cyclone duct carrying most of the dried and pulverized material and the water droplets with it. In addition to the air set in motion by the spinning chains, air from the recirculating blower issues out as a jet which is tangential to the torus. This jet splits into two streams, one of which lifts up the material between the torus periphery and the KDS chamber and carries it above the torus and then on to the cyclone. The other stream assists in the evacuation of the particles through the cyclone duct leading to the cyclone

The dry particles and water droplets are carried by the air in the cyclone duct to a conventional cyclone. No reabsorption of the water by the particles takes place because of the low concentrations and small residence time. The dry particles come out through an outlet star valve at the cyclone bottom and the cleaned air and water droplets leave through the cyclone outlet on the top only to be pumped back into the KDS chamber by the recirculating blower. As explained earlier, the air and the water droplets enter the KDS chamber as a jet. There is a vapor vent above the jet. A small part of the air escapes through the vapor vent carrying most of the water droplets with it. A water-air aerosol issues out of the vapor vent as a plume. There are actually 4 jets but only one of them is shown in the diagram.

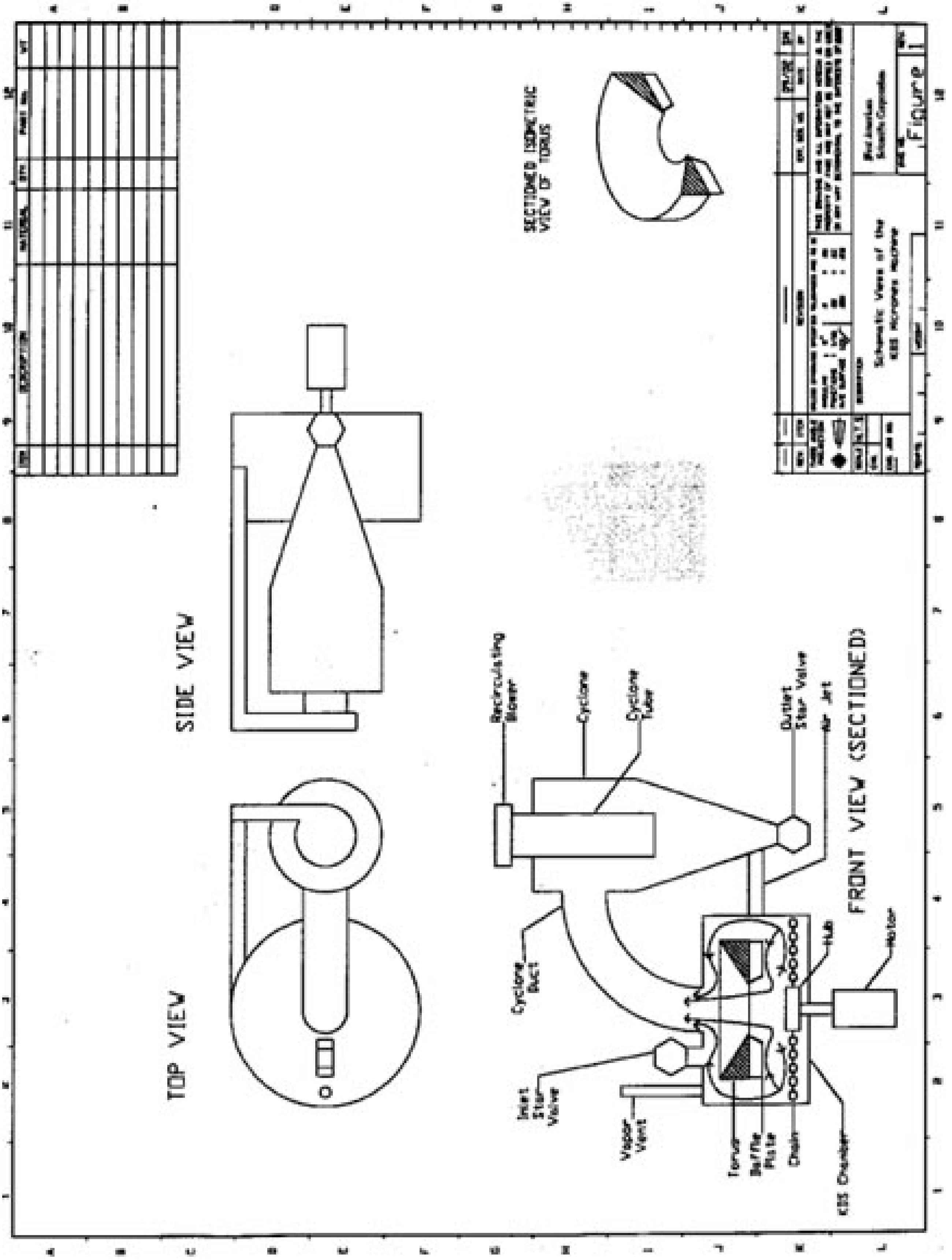
It is believed that pathogen kill occurs mainly due to kinetic heating of the particles when they collide against the baffle plates, chains, chamber sides, etc. Calculations show that these multiple impacts can briefly raise the temperature of the particles beyond what is necessary to pasteurize them. The residence time of the particles inside the KDS Micronex is of the order of a minute while the internal temperature is above 80^0 C, thus enabling the KDS Micronex to be registered by the U.S. EPA as a pesticide device establishment. Conjecturally, it is also possible that the enormous accelerations endured by the particles may burst the cell walls of the pathogens killing them. Also, the odor of the dry powder produced by the KDS Micronex is almost imperceptible in comparison to that of the raw material. This reduction in odor is related to the drying and pathogen kill.

Mention should also be made of the classifier - a device in this machine which can change the particle size of the product coming out. Resembling a spinning squirrel cage whose rotational speed can be varied, the classifier is located right above the chamber in the duct leading to the cyclone. Essentially, it rejects oversize particles into the grinding chamber where they are ground further. It has been found that the classifier also influences the final moisture content of the product since it controls the residence time of the material inside the KDS grinding chamber.

Some performance data on the KDS Micronex are shown in Table F. Note that the last column is the sum of the drying *and* grinding energies, since both operations are inseparably combined within the KDS Micronex. Even if it is assumed the last column represents only drying energy, it is clear that, in many cases, the KDS Micronex uses less energy to dry than the latent heat of water. In contrast, drum dryers use the energy equivalent of twice the latent heat of water. Thus, *the KDS Micronex uses about 70 % less energy than a drum dryer*, because it mainly uses mechanical energy, not heat, to dewater the raw material. However, since this energy is supplied in the form of shaft power, *the KDS Micronex has a 20 % drying cost advantage over a natural gas fired drum dryer, based on contemporary electricity and natural gas prices*.

Table F. Performance data of the KDS Micronex grinder-dryer

Substance	Feed Rate kg/hour	Moisture In %	Power kW	Output Rate kg/hour	Output Particle Diameter	Moisture Out %	Water Removal	Water Removal Energy
		(wet basis)			(microns)	(wet basis)	Rate (kg/hr)	kJ/kg
								of water
Deinking Sludge	1204.074	51	110	797.28	-	26	406.794	973.4657
Layer Manure	2062.962	47	130	1713.699	600	35	349.263	1339.964
Cow+Chicken Manure	1377.12	40	130	1087.2	600	24	289.92	1614.238
Sewage Screenings	622.422	50	110	389.127	-	20	233.295	1697.422
Broiler + human feces	563.079	44	120	313.929	600	21	249.15	1733.895
Coal	2174.4	15	140	1925.25	75	4	249.15	2022.878


TOP VIEW
SIDE VIEW
SECTIONED ISOMETRIC VIEW OF TORUS
FRONT VIEW (SECTIONED)
Recirculating Blower
Cyclone
Cyclone Tube
Outlet Star Valve
Air Jet
Cyclone Duct
Inlet Star Valve
Vapor Vent
Torus
Baffle Plate
Chain
KDS Chamber
Hub
Motor
Figure