THE CONTROL OF POWDER DETERGENT BULK DENSITY BY MEANS OF COUNTERCURRENT SPRAY DRYER

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ABSTRACT

In the bulk density control of powder detergents, production from counter –current spray –dryer was studied by using centrifugal pressure nozzle. The effect of the several variable on the bulk density, moisture content, and particle size is summarized in tables (1, 2, 3, 4, 5, and 6). It has been found that the bulk density of dried products increases with decrease in orifice nozzle diameter. The product bulk density varied from 249 to 340 kg/m^3 (Runs 30 and 33). This variation is due to the puffing degree of particle, moisture content, and average particle size. In some instances the bulk density varied directly with average particle size (controlled by nozzle diameter) and in others inversely with particle size (controlled by air temperature).

The type of particle formed, however, is very dependent on the characteristics of the material being dried. It was found that the increase in the feed flow rate causes an increase in the bulk density and moisture content, while the increase in feed temperature will cause increase in the bulk density and decrease in the moisture content increasing feed concentration and atomization pressure has a little effect on the bulk density. The moisture content an bulk density of dried product are found to decrease with increasing the air flow rate and /or its temperature.

INTRODUCTION

Detergents must be viewed as consumer goods derived from industrial production operations. This means, for example, that there precise formulation is determined by more than just their intended purpose: the number and kind of raw materials to be processed as a direct effect on production and can, therefore influence aspects of the formulation as well. Production technology is responsible for establishing certain important qualitative characteristics of a product: degree of retention of raw material activity, bulk density, moisture content, homogeneity, particle size distribution, flowability, dust behavior, and dispersing and flushing properties.

The bulk density is an important characteristic, which must be controlled because it is effect directly on the charging weight of the product per chosen fixed volume (carton). A definite weight of product must be placed in a box of a certain size.

EXPERIMENTAL WORK

Feed System

The feed (slurry) system used are described below:

Ingredients	Composition, %		
	Batch-1	Batch-2	Batch-3
Alkylbenzen-sulfonates	15	15	15
Sodium tripolyphosphate	17	19	21
Sodium sulphate	17	19	21
Sodium silicate	2	2	2
Sodium chloride	3	3	3
Water	46	42	38

Description of Equipments

A schematic diagram of the experimental apparatus is presented in figure (1). This investigation has been carried out on a countercurrent spray drying towers, which has the following parameters:

Construction material	Carbon steel
Diameter, m	6
Cylinder height, m	20
Insulation material	Glass fiber
Insulation thickness, mm	0.11
Drying air requirements, kg/s	4, 3-4.9
Tower inlet temperature, k	520-625
Tower outlet temperature, k	345-385
Output capacity, kg/s	<1.1

The atomizer level is approximately on level with the upper cone base. Centrifugal type mono fluid pressure nozzles have been used for atomization. The nozzle consists of a chamber with tangential inlet, which applies to the liquid a swirling motion prior to outlet from the capsule, which is the real orifice, figure (2). The construction materials of the nozzles are stainless steel or tungsten carbide. Three types of nozzle of different inside orifice diameters (2.5, 3.0, and 4.0 mm) were employed; since the chamber inside diameter was (10 mm).

Two types of pumps were used for atomization purposes: the first was of rotary type (screw pump) which was reciprocating pump (power for the second pump. The second was reciprocating pump (power driven tetra piston pump) which was used for attaining high pressures (2.5-6.0 Mpa) with flowrate up to 0.4 Kg/s.

The airflow through the spray dryer installation was produced by a centrifugal fan, and mixed directly with fuel –oil burner. The rate of fuel-oil consumption was about (90.0000-100.0000 cm^3/s); while the specific gravity is 0.876. The fuel-oil was injected inside the burner through the nozzle at a pressure of (0.5-0.7 Mpa).

The air exhaust from the tower carried dust particles which had to be greatly eliminated by using eight dry-cyclone. A dry-cyclone is a centrifugal particle separator (mechanical separator). In the technique of powder removal from dry cyclones, hoppers are fitted to cyclones to reduce powder re-entrainment caused by the intensive vortex area at the cyclone base. Cyclone is operated at pressures of (93-100 Kpa) and temperature exceeding 340°K. The size of the dust particles removed ranges between (50-150 microns).

A metallic filter between the crutcher and the screw pump is used for removing metallic objects and large particles or agglomerates that might otherwise clog the spry nozzles. The filter consists of a metallic cylinder with 2mm holes diameter.

Experimental procedure

Individual solid and liquid components were drawn off from silos or tanks and introduced batchwise into scales and they were premixed to a slurry in the first crutcher continuously. The homogeneity to slurry was completed by using a second crutcher. The temperature of the slurry was controlled by using direct steam inside the crutcher.

Conversion of the slurry into powder requires the use of pressure of up to 2.5Mpa. Two types of pumps were used for this process, screw pump and high presser pump.

The slurry sample was taken from a valve, at place after the filter directly. The following analysis was determined: activity percentage, moisture percentage, and temperature measurements.

Feed rate and the atomization pressure of the slurry were controlled by means of the high-pressure pump speed, number of the nozzles, and the size of the nozzles.

Hot air from direct–fired air burner entered from a circular channel at the base of the cylindrical part of the tower with slight rotary motion. The exhaust air drawn from the top of the tower was maintained a slight vacuum pressure inside the tower.

The inlet and outlet air temperatures were measured directly with a temperature gauge, and chacked by the thermometer. Also the inlet burner temperature was directly read from the temperature gauge.

The exhaust air was passed through dry cyclones to separate the fine particle. The fine fraction was usually returned to feed preparation or mixed with final product.

The inlet air temperature was controlled by decreasing or increasing the flow rate of flue – oil consumption, while the air flworate was controlled by using side exhaust vent, before air was allowed into the base of the base of the tower.

The dried powder would leave the base of the drying tower and transported via a converyor belt to an air lift. During passage on the belt, experimental sample was taken and its properties (bulk density, moisture content, and average particle size) were measured.

RESULTS AND DISCUSSION

Slurry Humidity

The increase in feed moisture simply means (from heat balance) higher moisture in the product, as shown in Figure–3. Also the increasing of feed moisture results increasing in average particle size. Generally high particle moisture means a lower boiling point, giving more puffing, and that results in a lower density. However, a higher particle moisture means more evaporation, therefore, lower air temperature, which towards higher density. However Figure–4 show that the change in bulk density with increase in slurry humidity is little.

Slurry Temperature

In general the increasing of slurry temperature cause a lowering in slurry viscosity. This phenomenon is due to the great salts solubility. However, increasing feed temperature causes de –aeration in the slurry and high feed density results (Figure –15) which causes an increase in bulk density of dried product.

Since the increasing in feed temperature causes decrease in moisture of dried product, while the bulk density increased. Figures(5,6) show these relations. The effect of feed temperature on average particle size can be observed in Table –2. The increase in feed temperature causes decrease in temperature difference between droplet and air temperature. This means lower steam puffing causing a decrease in average particle size.

In the two considered cases (feed concentration and feed temperature), it is found that the viscosity decrease of slurry, due to a humidity increase, has little effect on bulk density, while viscosity decrease due to a feed temperature raising causes a bulk density increase.

Effect of Feed Rate

The relation between the feed rate and the atomizing pressure has been determined experimentally for different nozzle sizes, as shown in Figure –16.

The effect of feed rate on bulk density, and moisture content, is shown in Figure(7,8). The figures indicate that the bulk density is increased with increasing the feed rate. This due to the fact that air temperature will decrease inside the tower and the air humidity will increase; and this will cause more accumulation of moisture inside the particle and lowering in steam puffing causing a high density and a lower average particle size.

Effect of Atomizing Pressure

The effect of atomizing pressure on bulk density, moisture, and average particle size has been studied. Figure–9 show that a little change in bulk density is obtained at the operating pressure range used.

The increase in atomizing pressure causes a decrease in droplet size so a slight decrease of moisture content has appeared and also a lowering in average particle size has been obtained, as shown in Figure –10, and Table-6.

Effect of Inlet Air Temperature

The effect of air temperature on bulk density and moisture content of dried product has been tested. The experiments were carried out at inlet air temperature range of (523-568K). the air temperature influence is very clearly shown in Figures(11,12) for bulk density and moisture content. The figures shown that an increase in air temperature causes a lowering in bulk density and moisture content. This lowering is due to the fact that increasing the inlet air temperature causes more evaporation due to higher temperature difference and hence lower product moisture. The higher temperature also means more puffing due to steam formation, hence a lower bulk density, and higher average particle size.

Air Flow Rate Effect

The air flow rate is plotted against bulk density, and moisture content, as shown in Figures(13,14). The effect of increasing the air flow rate means simply more air at the same inlet temperature. This means a higher exhaust temperature, therefore more total evaporation, a lower product moisture, and more steam puffing causing a lower bulk density and a higher average particle size.

CONCLUSIONS

The control of detergents powder bulk density has been studied by using counter current spray – dryers, with centrifugal pressure nozzle at (2.5, 3.25, and 4.0mm) orifice diameter.

The experimental results shown that the bulk density increase depends strongly on the nozzle diameter, which might be used. The results showed also that the bulk density increase as the inlet air flow rate and /or temperature decrease, but the moisture content of dried product increases.

The effect of feed viscosity was studied and the results showed that the bulk density is increase as the viscosity increases, when the viscosity is a function of feed temperature; while the bulk density has little change with increase in viscosity, when the viscosity is a function of feed concentration.

The effect of feed rate was also studied and its results showed that the bulk density of dried product is increased with increase in feed rate. At higher value of feed rate the moisture content of dried product would be increased. The result showed that the atomization pressure has a little effect on the bulk density with different nozzle diameters. The optimum range of bulk density of the heavy duty detergent is (300-350 Kg/m^3) and mostly with in rang (310-330 Kg/m^3), and the moisture contents range is (8-12 wt.%); while the average particle size range is (340-470 microns). The experimental results show that the optimum operating conditions to get these values can be obtained from runs number (1,16).

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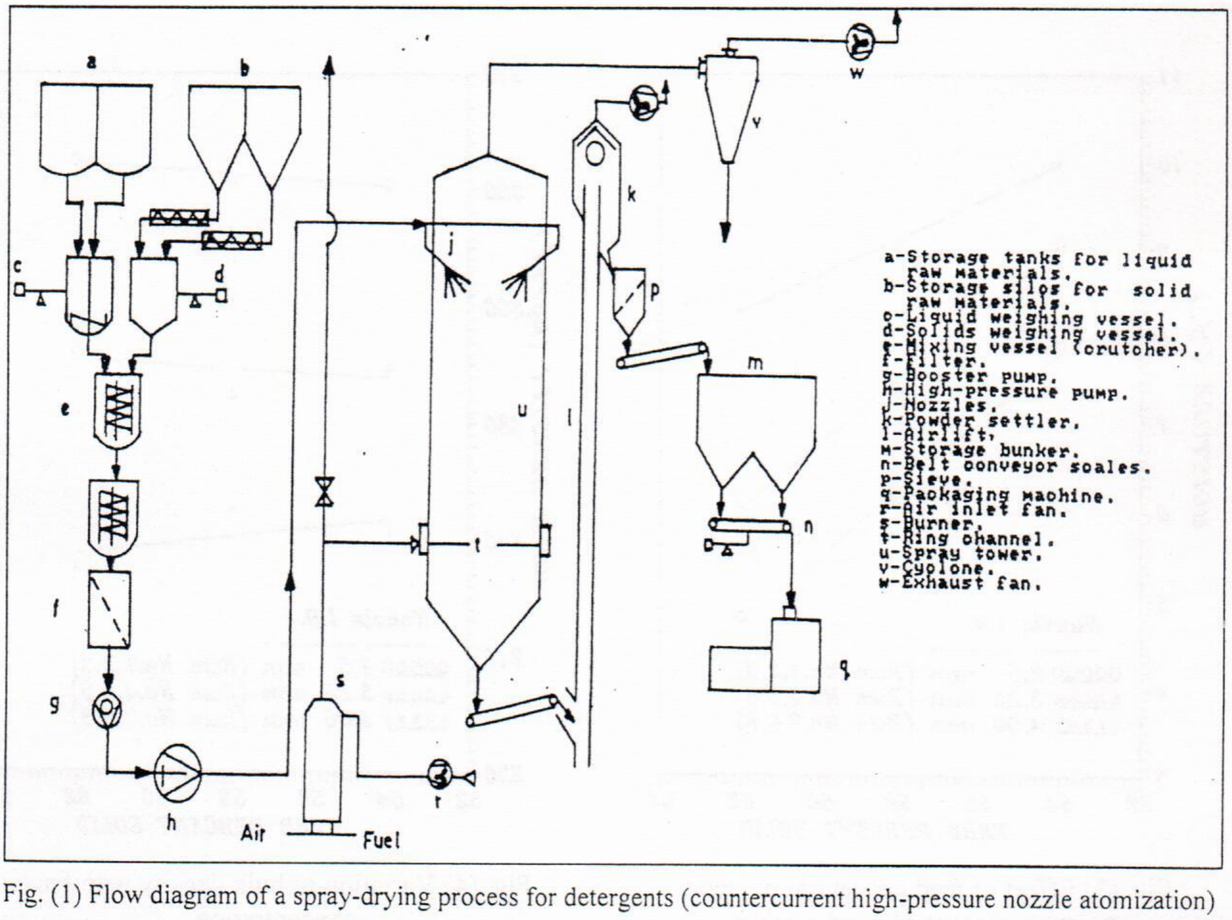

Fig. (1) Flow diagram of a spray-drying process for detergents (countercurrent high-pressure nozzle atomization)

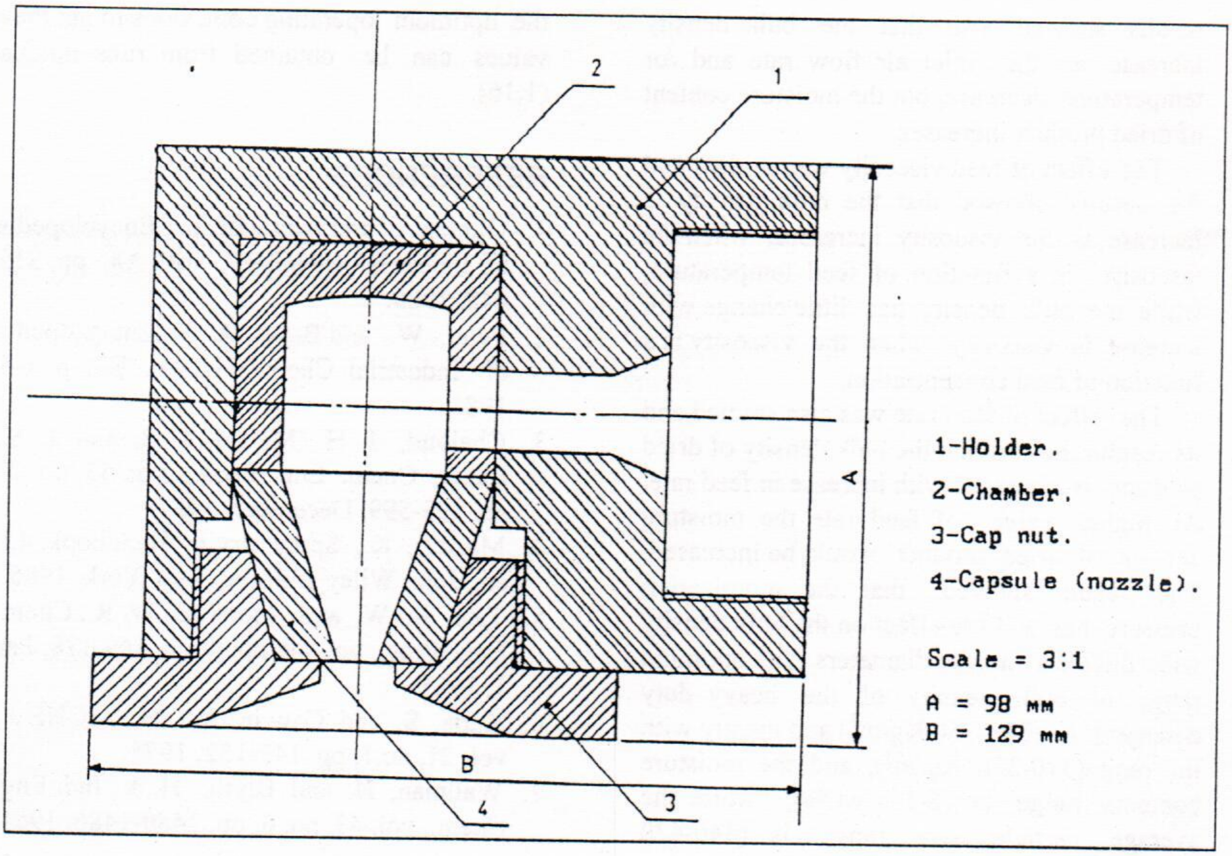

Fig. (2) Centrifugal pressure nozzle construction with tangential liquid entry

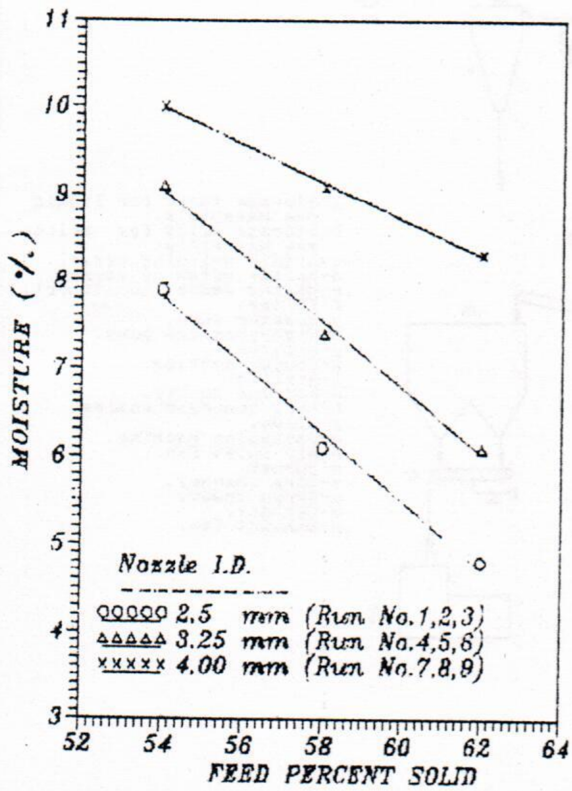

Fig. (3) Effect of feed concentration upon moisture content of dried product

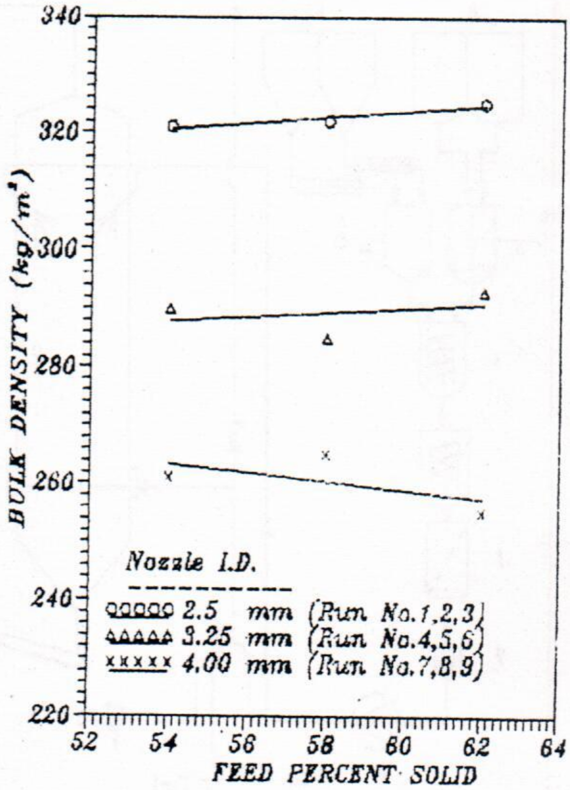

Fig. (4) Variation of bulk density with feed concentration

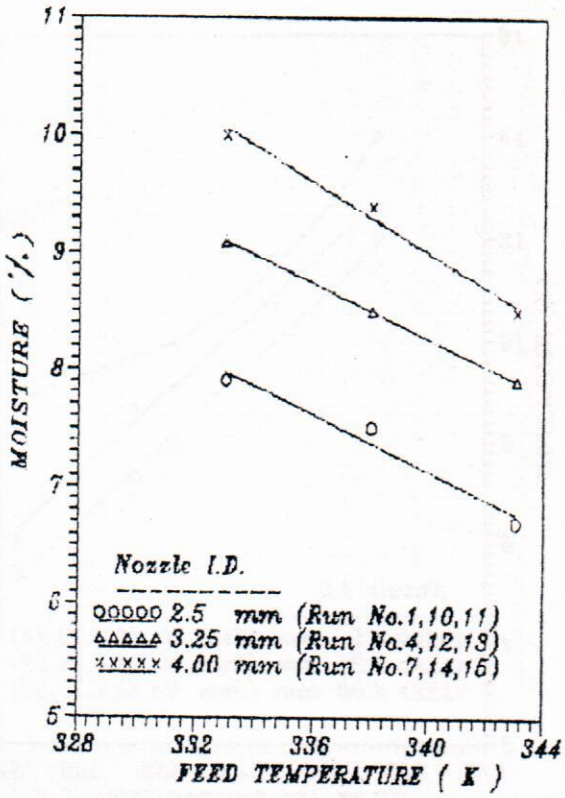

Fig. (5) Effect of feed temperature upon moisture content of dried product

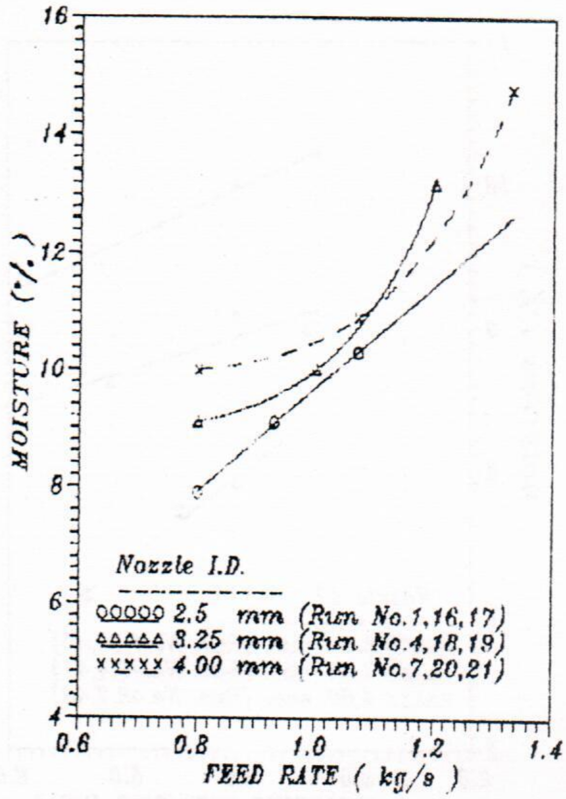

Fig. (7) Effect of feed rate upon moisture content of dried product.

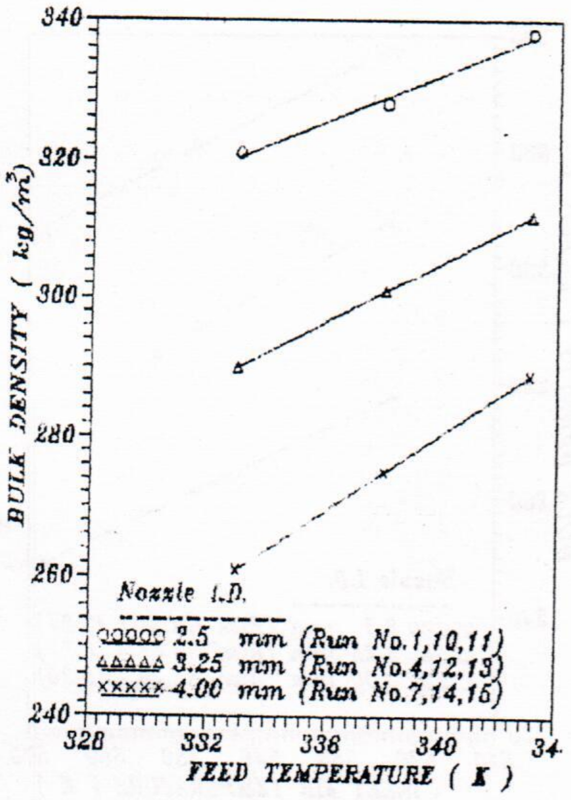

Fig. (6) Variation of bulk density with feed temperature.

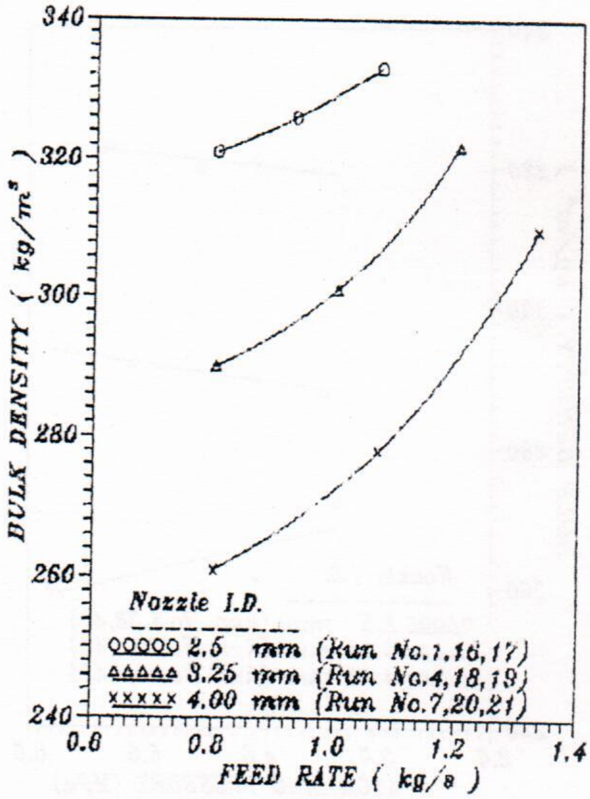

Fig. (8) Variation of bulk density with feed rate.

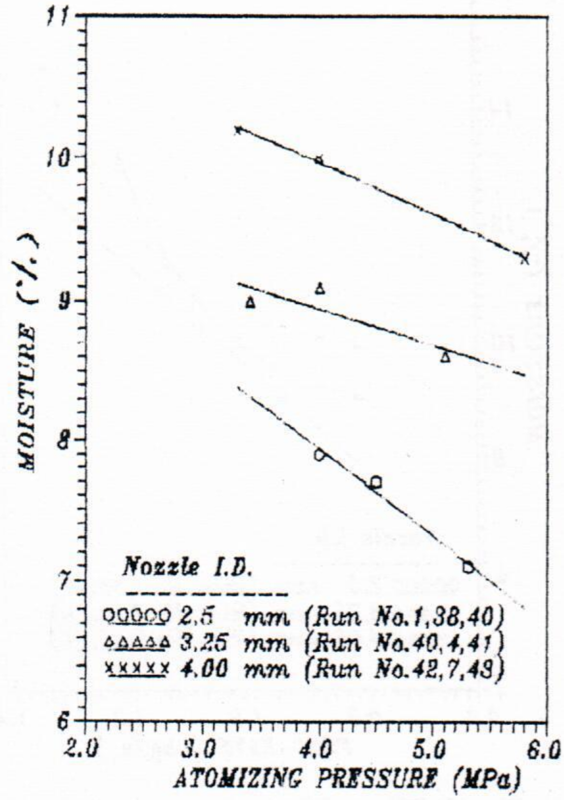

Fig. (9) Effect of automization pressure upon moisture content of dried product.

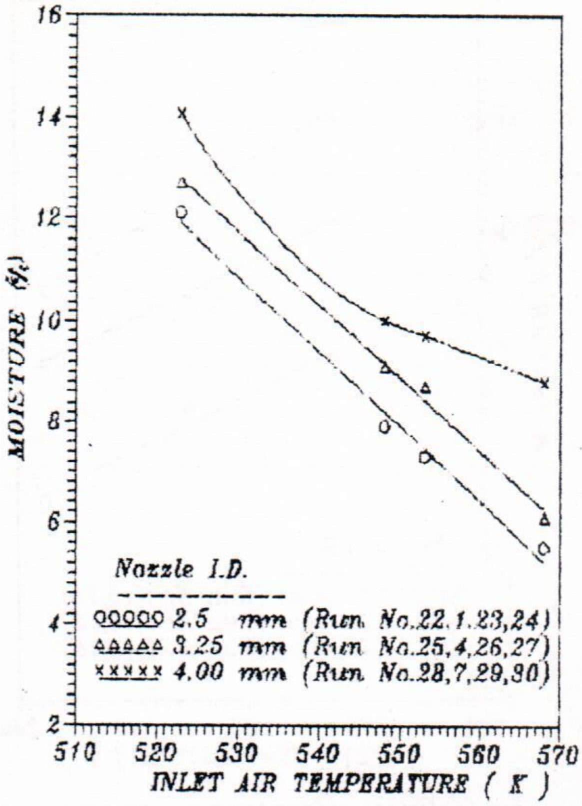

Fig (11) Effect of inlet air temperature upon moisture content of dried product.

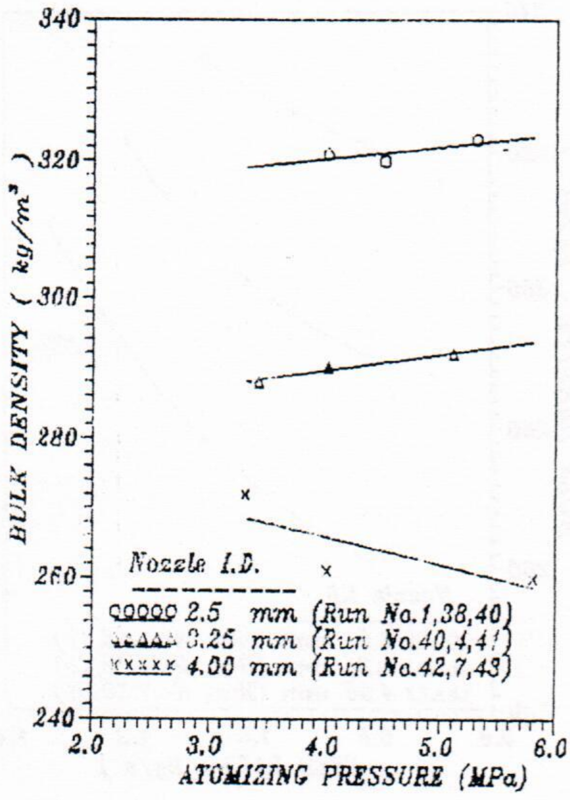

Fig. (10) Variation of bulk density with automization pressure

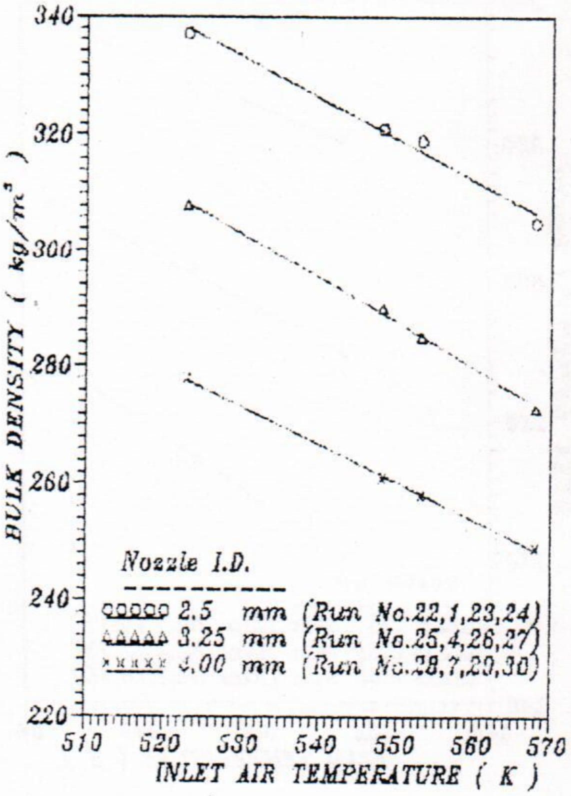

Fig (12) Variation of bulk density with inlet air temperature.

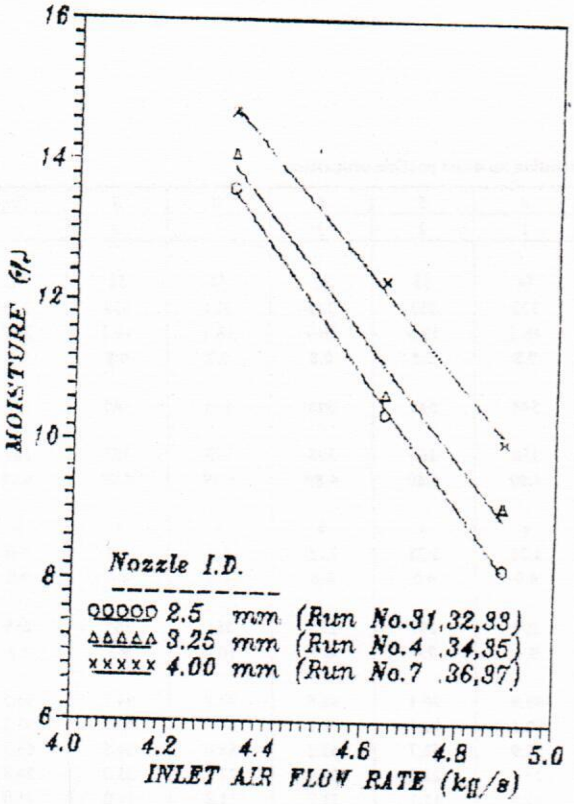

Fig. (13) Effect of inlet air flow rate moisture content of dried product.

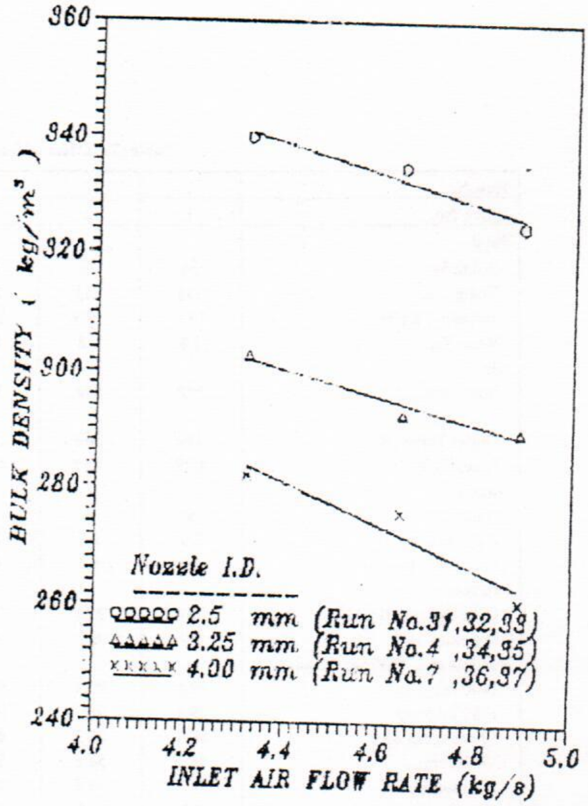

Fig. (14) Variation of bulk density with inlet air temperature.

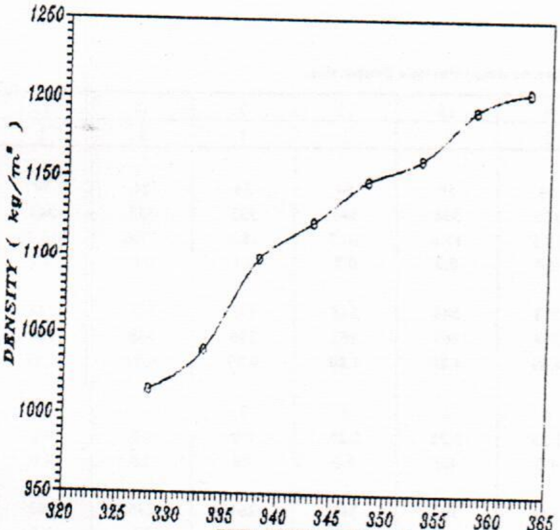

Fig. (15) Variation of density with temperature at feed concentration = 54.

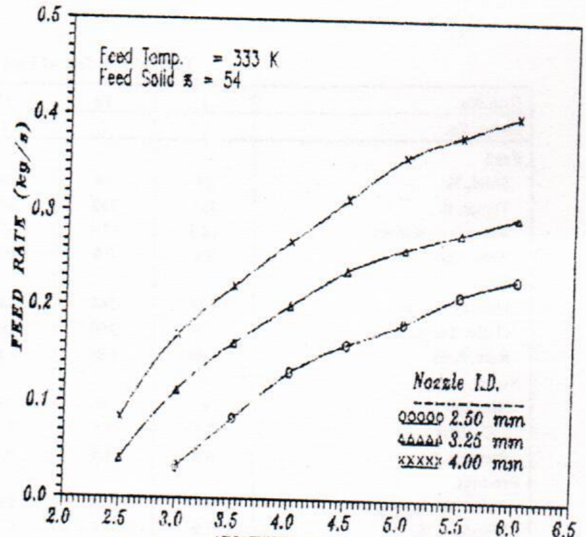

Fig. (16) Effect of atomizing pressure upon feed flow rate for a single nozzle.

Table (1), Effect of feed concentration on dried particle properties.

Run No.	1	2	3	4	5	6	7	8	9
Batch No.	1	2	3	1	2	3	1	2	3
Feed									
Solid, %	54	58	62	54	58	62	54	58	62
Temp. , K	333	333	333	333	333	333	333	333	333
viscosity, Kg/m.s	18.5	19.3	20.7	18.5	19.3	20.7	18.5	19.3	20.7
Rate, Kg/s	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Air									
Inlet Temp., K	548	548	548	548	548	548	548	548	548
Outlet Temp., K	359	360	363	358	360	365	358	361	367
Rate, Kg/s	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89
Nozzle									
Number	6	6	6	4	4	4	3	3	3
I. D., mm	2.5	2.5	2.5	3.25	3.25	3.25	4.0	4.0	4.0
Pressure, Mpa	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Product									
Bulk Density, Kg/M^3	321	322	325	290	285	293	261	265	255
Moisture, %	7.9	6.1	4.8	9.1	7.4	6.1	10.0	9.1	8.3
Particle size, %Finer Than									
1400 microns	99.8	99.4	99.5	95.9	96.1	96.6	94.2	94.7	94.9
1180 microns	99.5	98.1	98.1	92.8	93.1	93.7	89.8	90.8	91.2
600 microns 89.0	89.0	87.3	87.5	59.9	62.7	63.2	55.0	59.5	60.3
335 microns	46.2	58.6	59.1	27.1	25.2	26.6	27.1	25.0	24.8
180 microns	14.7	14.7	14.9	11.5	11.1	11.7	11.8	11.0	11.0
38 microns	2.3	2.6	2.4	2.1	2.1	2.2	1.5	1.4	1.6
Average Particle Size, microns	403	392	388	612	602	592	651	632	627

Table (2), Effect of Feed Temperature on dried Particle Properties.

Run No.	1	10	11	4	12	13	7	14	15
Batch No.	1	1	1	1	1	1	1	1	1
Feed									
Solid, %	54	54	54	54	54	54	54	54	54
Temp., K	333	338	343	333	338	343	333	338	343
Viscosity, Kg/m.s	18.5	17.6	16.7	18.5	17.6	16.7	18.5	17.6	16.7
Rate, Kg/s	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Air									
Inlet Temp., K	548	548	548	548	548	548	548	548	548
Outlet Temp., K	359	360	363	358	361	363	358	360	364
Rate, Kg/s	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89
Nozzle									
Number	6	6	6	4	4	4	3	3	3
I. D., mm	2.5	2.5	2.5	3.25	3.25	3.25	4.0	4.0	4.0
Pressure, Mpa	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Product									
Bulk Density, Kg/m^3	321	328	338	290	301	312	261	275	289
Moisture, %	7.9	7.5	6.7	9.1	8.5	7.9	10.0	9.4	8.5
Particle Size, %Finer Than									
1400 microns	99.8	99.8	99.8	95.9	96.3	96.0	94.2	94.5	94.9
1180 microns	99.5	99.5	99.5	92.8	93.6	93.4	89.9	90.6	90.9
600 microns	89.0	89.9	89.8	59.9	62.3	63.4	55.0	57.8	59.3
355 microns	46.2	50.3	52.6	27.1	29.5	29.8	27.1	29.1	30.6
180 microns	14.7	15.9	19.6	11.5	13.2	13.7	11.2	13.0	13.5
38 microns	2.3	4.0	3.2	2.1	2.6	2.9	1.5	1.9	1.8
Average Particle Size, microns	403	388	378	612	589	584	651	629	616

Table (3), Effect of Feed rate on dried Particle Properties.

Run No.	1	16	17	4	18	19	7	20	21
Batch No.	1	1	1	1	1	1	1	1	1
Feed									
Solid, %	54	54	54	54	54	54	54	54	54
Temp., K	333	333	333	333	333	333	333	333	333
Viscosity, Kg/m.s	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Rate, Kg/s	0.8	0.93	1.07	0.8	1.0	1.2	0.8	1.07	1.33
Air									
Inlet Temp., K	548	548	548	548	548	548	548	548	548
Outlet Temp., K	359	353	351	358	352	349	358	351	347
Rate, Kg/s	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89
Nozzle									
Number	6	7	8	4	5	6	3	4	5
I. D., mm	2.5	2.5	2.5	3.25	3.25	3.25	4.0	4.0	4.0
Pressure, Mpa	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Product									
Bulk Density, Kg/m^3	321	326	333	290	301	322	261	278	310
Moisture, %	7.9	9.1	10.3	9.1	10.0	13.2	10.0	10.9	14.8
Particle size, % Finer Than									
1400 microns	99.8	99.8	99.8	95.0	95.8	95.9	94.2	94.3	94.8
1180 microns	99.5	99.5	99.4	92.8	92.8	93.0	89.9	90.3	90.7
600 microns	89.0	89.1	89.6	59.9	61.8	61.9	55.0	55.7	57.8
355 microns	46.2	48.2	49.1	27.1	27.2	29.9	27.1	27.5	29.1
180 microns	14.7	14.9	14.8	11.5	11.8	12.0	11.2	11.4	12.0
38 microns	2.3	2.2	2.2	2.1	2.2	2.3	1.5	1.5	1.7
Average Particle size, microns	403	399	395	612	604	596	651	645	629

Table (4), Effect of inlet air temperature on dried Particle Properties.

Run No.	22	1	23	24	25	4	26	27	28	7	29	30
Batch No.	1	1	1	1	1	1	1	1	1	1	1	1
Feed												
Solid, %	54	54	54	54	54	54	54	54	54	54	54	54
Temp., K	333	333	333	333	333	333	333	333	333	333	333	333
Viscosity, Kg/m.s	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Rate, Kg/s	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Air												
Inlet Temp., K	523	548	553	568	523	548	553	568	523	548	553	568
Outlet Temp., K	351	359	360	368	350	358	359	366	353	358	360	368
Rate, Kg/s	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89
Nozzle												
Number	6	6	6	6	4	4	4	4	3	3	3	3
I. D., mm	2.5	2.5	2.5	2.5	3.25	3.25	3.25	3.25	4.0	4.0	4.0	4.0
Pressure, Mpa	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Product												
Bulk Density, Kg/m^3	337	321	319	305	308	290	285	273	278	261	258	249
Moisture, %	12.0	7.9	7.3	5.5	12.7	9.1	8.7	6.1	14.1	10.0	9.7	8.8
Particle size, % Finer Than												
1400 microns	99.8	99.8	99.7	99.7	96.5	95.9	96.0	94.9	95.0	94.2	93.5	93.8
1180 microns	99.6	99.5	99.5	99.3	94.1	92.8	92.8	91.0	91.0	89.9	89.2	89.0
600 microns	89.7	89.0	88.8	86.5	65.9	59.9	58.8	58.2	63.0	55.0	53.7	47.9
355 microns	50.3	46.2	45.7	43.5	38.4	27.1	24.7	25.3	35.9	27.1	26.2	22.0
180 microns	14.8	14.7	14.4	12.7	20.5	11.5	11.2	11.1	16.5	11.8	10.8	10.4
38 microns	2.2	2.3	2.1	2.1	2.5	2.1	2.0	1.8	2.5	1.5	1.3	1.3
Average Particle size, microns	391	403	406	423	541	612	521	635	583	651	666	699

Table (5), Effect of inlet air flow rate on dried Particle Properties.

Run No.	31	32	33	4	34	35	7	36	37
Batch No.	1	1	1	1	1	1	1	1	1
Feed									
Solid, %	54	54	54	54	54	54	54	54	54
Temp., K	333	333	333	333	333	333	333	333	333
Viscosity, Kg/m.s	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Rate, Kg/s	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Air									
Inlet Temp., K	548	548	548	548	548	548	548	548	548
Outlet Temp., K	358	354	350	358	353	351	358	355	353
Outlet Wet-Bulb Temp., k	285	285	285	-	-	-	-	-	-
Atmospheric Temp., K	291	291	291	-	-	-	-	-	-
Rate, Kg/s	4.89^A	4.64^B	4.32^C	4.89^A	4.64^B	4.32^C	4.89^A	4.64^B	4.32^c
Nozzle									
Number	6	6	6	4	4	4	3	3	3
I. D., mm	2.5	2.5	2.5	3.25	3.25	3.25	4.0	4.0	4.0
Pressure, Mpa	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Product									
Bulk Density, Kg/m^3	325	335	340	290	293	303	261	276	282
Moisture, %	8.2	10.4	13.6	9.1	10.7	14.1	10.0	12.3	14.7
Temp., K	343	341	340	-	-	-	-	-	-
Particle size, %Finer Than									
1400 microns	99.8	99.8	99.8	95.9	95.8	96.4	94.2	94.3	95.1
1180 microns	99.6	99.5	99.7	92.8	92.7	93.7	89.9	90.3	91.6
600 microns	88.9	90.1	90.5	59.9	60.4	62.7	55.0	58.2	62.0
355 microns	46.6	54.3	54.9	27.1	30.8	34.6	27.1	26.7	29.9
180 microns	14.9	16.3	17.1	11.5	12.3	15.0	11.8	11.3	13.3
38 microns	2.3	2.3	2.6	2.1	2.2	2.1	1.5	1.5	1.8
Average Particle size, microns	402	379	374	612	601	573	651	637	603

A) Close vent B) Semi-close vent C) Open vent

Table (6), Effect of atomization pressure on dried particle properties.

Run No.	1	38	39	40	4	41	42	7	43
Batch No.	1	1	1	1	1	1	1	1	1
Feed									
Solid, %	54	54	54	54	54	54	54	54	54
Temp., K	333	333	333	333	333	333	333	333	333
Viscosity, Kg/m.s	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Rate, Kg/s	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Air									
Inlet Temp., K	548	548	548	548	548	548	548	548	548
Outlet Temp., K	359	359	358	357	358	356	360	358	358
Rate, Kg/s	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89	4.89
Nozzle									
Number	6	5	4	5	4	3	4	3	2
I. D., mm	2.5	2.5	2.5	3.25	3.25	3.25	4.0	4.0	4.0
Pressure, Mpa	4.0	4.5	5.3	3.4	4.0	5.1	3.3	4.0	5.8
Product									
Bulk Density, Kg/m^3	321	320	323	288	290	292	272	261	260
Moisture, %	7.9	7.7	7.1	9.0	9.1	8.6	10.2	10.0	9.3
Particle Size, % Finer Than									
1400 microns	99.8	99.4	99.5	96.0	95.9	96.0	92.1	94.2	94.3
1180 microns	99.5	99.0	99.0	93.1	92.8	92.9	85.9	89.9	90.4
600 microns	89.0	88.3	86.7	59.6	59.9	61.5	42.6	55.0	56.1
355 microns	46.2	49.8	49.3	23.3	27.1	29.4	19.4	27.1	25.6
180 microns	14.7	30.9	41.5	9.8	11.5	11.4	13.1	11.8	11.3
38 microns	2.3	2.4	2.2	3.7	2.1	2.2	2.3	1.5	1.5
Average Particle size, microns	403	377	367	621	612	600	740	651	648