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EXPERIMENTS WITH RADIANT HEAT FOR DRYING MINERALS

R. A. WYMAN AND T. MARSHALL

MINERAL PROCESSING DIVISION

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EXPERIMENTS WITH RADIANT HEAT FOR DRYING MINERALS

by

R.A. Wyman* and T. Marshall**

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ABSTRACT

Bulk drying requirements of the Industrial Minerals Milling Section, Mineral Processing Division, Mines Branch, EMR, Ottawa, Canada, range from a few pounds to several tons of varied mineral materials at varying moisture contents. Experiments were carried out with two drying devices to see if a simple process would prove capable of handling these requirements satisfactorily. A system employing infrared heaters, with a face area just equal to that of the bottom of a vibrating conveyor over which they were suspended, was found capable of removing an average of 13.6 pounds (6.2 kg) of water for an average feed rate of 275 pounds (124 kg). This required 313 kilowatts of power per ton of solids treated at an approximate cost of $7.80 per ton dried.

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Direction des mines, Bulletin technique TB 183

EXPERIENCES SUR LE SECHAGE DES MINERAIS

PAR LA CHALEUR RADIANTE

par

R.A. Wyman* et T. Marshall**

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RESUME

La section de l'usinage, Division du traitement des minéraux, Direction des Mines, EMR, Ottawa, Canada, doit faire sécher des quantités variant entre quelques livres et plusieurs tonnes de diverses substances minérales à teneur variable en eau. Des expériences ont été effectuées à l'aide de deux appareils de séchage afin de vérifier si un procédé simple pourrait répondre à ce besoin de façon satisfaisante. Un système composé de radiateurs à l'infrarouge dont la surface était exactement égale à celle du fond d'un convoyeur à secousse au-dessus duquel ils étaient suspendus s'est montré capable d'enlever une moyenne de 13.6 livres (6.2 kg) d'eau pour un taux d'alimentation moyen de 275 livres (124 kg). Ceci a demandé 313 kilowatts par tonne de matière solide traitée ce qui correspond à un coût approximatif de $7.80 par tonne séchée.

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INTRODUCTION

The removal of moisture from minerals in a processing laboratory is a daily requirement. The materials to be dried may vary from raw lumps to fine-grained process products. The amounts involved may range from a few grams to several tons. Lump materials can usually be dried by exposure to air, but as the size of particle becomes smaller air drying becomes impracticable, even for small amounts.

Materials larger than about 4 mesh (4.76 mm) drain rapidly and generally retain only a small amount of water as surface moisture. The amount of water retained increases as particle size decreases. Some materials will retain more than their own weight of water. Many fine materials are sticky when damp and tend to agglomerate.

Amounts less than about 10 pounds (4.5 kg) of most mineral materials may be readily dried in an electric oven at temperatures below the boiling point of water. Larger amounts, up to about 100 pounds (45 kg), can usually be dried in a few hours under infrared driers. Still larger amounts require some form of continuous drying.

Bulk drying needs in the Industrial Minerals Milling Section of the Mineral Processing Division of the Mines Branch are usually for amounts below 1 ton (907.6 kg), but occasionally for several tons. Although a large drying facility is not needed, there is a need for considerable versatility. No suitable means was available to slowly but continuously convey material beneath the existing infrared drier, which covered a rectangular area of 12 ft^2 (1.08 m^2). It was therefore decided to suspend elements from the static drier above a 10 ft (3 m) vibrating conveyor.

Considerable success was achieved with this device and the experiments performed constitute Part 1 of this report. However, the CHROMALOX panels, which perform well as static driers, had inherent shortcomings for continuous operations. This was corrected by purchasing solar radiant heaters. Experiments performed with the improved device constitute Part 2 of the report.

PART 1

Description of Equipment

The drying unit was composed of two components - the conveyor and the heaters.

An Eriez vibrating tray conveyor was used. This consisted of a mild steel trough 10 ft (3 m) long, and 6 in. (15 cm) wide, with 3-in. (7.5-cm) sides, mounted on four equally spaced 40A vibrating drives fastened to a common base. Vibrating speed could be varied by a voltage controller over a scale of 0 to 120, with 110 volt 60 cycle current.

Two Chromalox static heater panels were suspended over the conveyor tray by means of wooden frames. The heater panels are each 46 in. (115 cm) long by 3 in. (7.5 cm) wide, with single heating rods drawing 1600 watts at 220 volts. However, the effective reflecting area is only 40 in. (100 cm) by 3 in. (7.5 cm) due to 3-in. (7.5-cm) blank ends on the panels. Thus with two panels suspended end to end over the conveyor only 80 in. (200 cm) of the 120-in. (300-cm) conveyor length was effectively exposed to the radiant heat. The gap between was partially filled by suspending two 250-watt infrared bulbs over the conveyor. A timing device was used to govern the heat level by controlling the proportion of each minute the heaters were active. For the experiments conducted the timer was set for continuous heating, at 100% active.

A Jeffrey vibratory feeder was used to regulate feed input to the head end of the drying conveyor and feed rate was controlled by a voltage regulator.

Figure 1 is a general view of the drying unit.

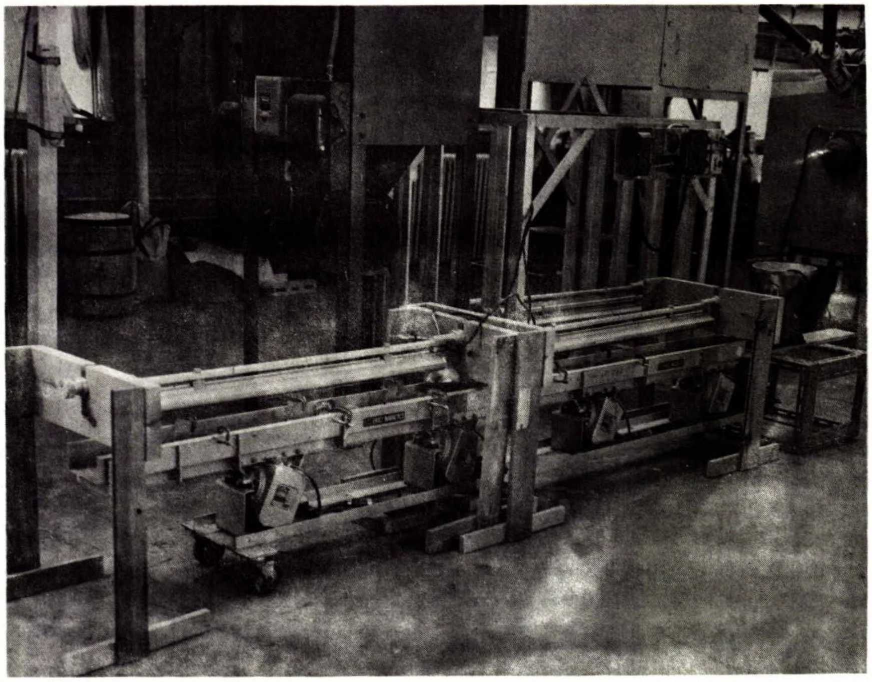

Figure 1. First Drying Unit

It became apparent from the initial trial run that some method would have to be devised for breaking up the bed of material as it moved along the conveyor so that the evaporating moisture could more readily escape. For fine materials it was necessary to break up pellets which formed near the feed end. A number of ploughs, scoops and baffles were tried before a system of simple "lifters" was adopted. The lifters consisted of light sheet-metal bent to conform with the inside of the conveyor trough and fastened so that the advancing bed of feed would be picked up, travel up the lifter slope and cascade over the lip and back to the conveyor bottom. The lifters were 6 in. (18 cm) in length and could be set at any slope to provide the desired height of cascading. Four different configurations of lifters were employed during the experiments, as indicated in Figure 2. Five lifters were used in all experiments.

Although the lifters greatly increased the speed of drying they did little to break up pellets. Because the pellets dried only on the outside, it was necessary to break them up and allow trapped moisture to escape. Again a number of trials were made before settling on "drags" and "rollers". The drags were pieces of 8-mesh (2.4-mm) screen cut in rectangles to fit inside the conveyor trough. These were fixed so that the moving bed would pass under them as they inclined back from the direction of flow. Since they were free to move up and down they served both to break up the pellets and to level the bed so that the action of rollers would be most effective. The drags were placed immediately after the lifters; usually three or four but occasionally two or five of the drags were used.

As the experiments progressed, it was found necessary to devise rollers of various kinds to meet different situations. The roller types used are depicted in Figure 3. Essentially the roller was a cylinder just under 6 in. (4.5 cm) in length, so that it would fit across the conveyor width without jamming. Rollers placed just ahead of lifters were free to rotate as the bed passed under them but kept from advancing by the slope of the lifter. The weight of the roller on the bed of partially pelletized material, which had been leveled by a drag, tended to break up and pulverize the pellets. Weight could be be varied as desired by the addition of steel rods to the interior of the roller.

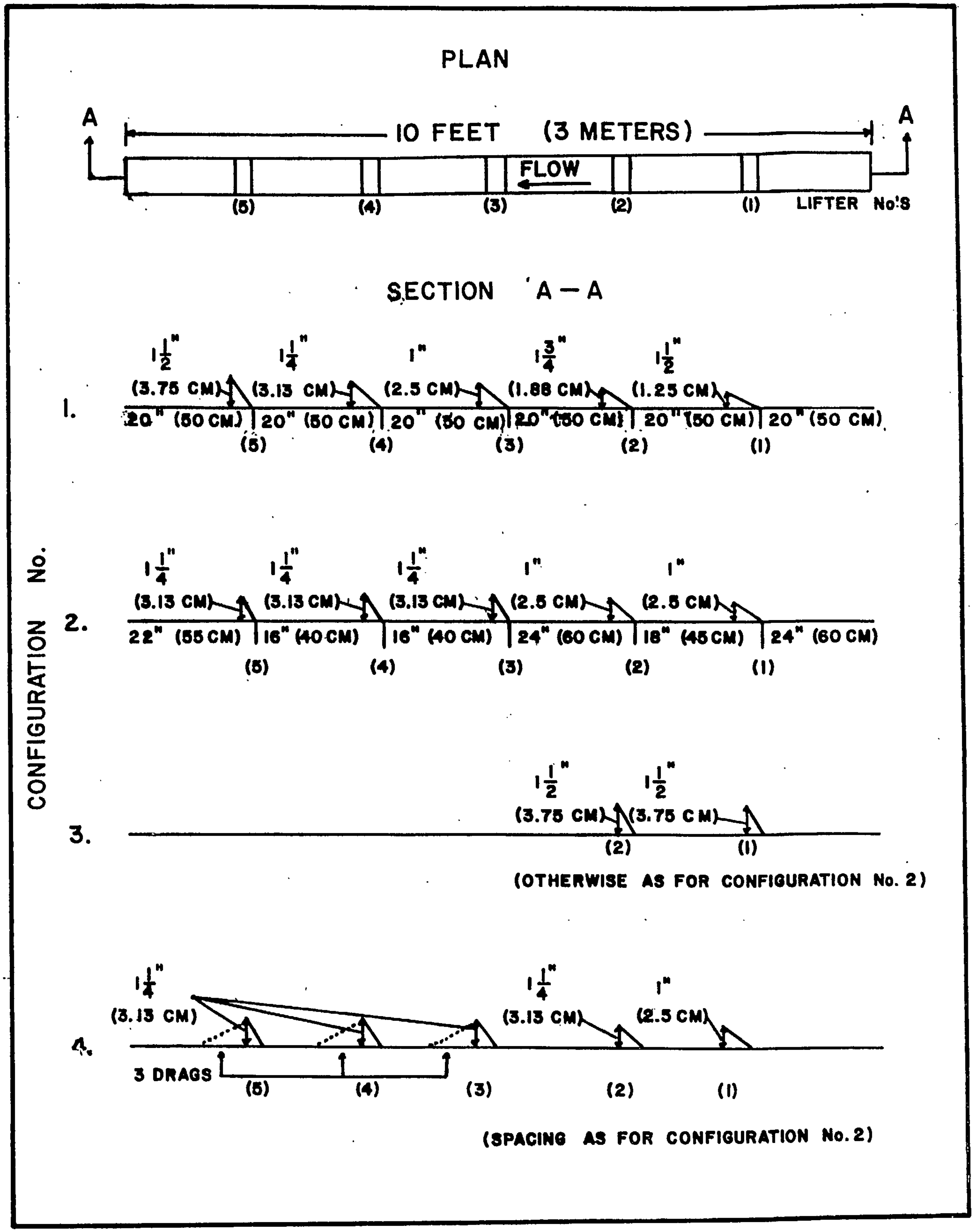

FIGURE 2. LIFTER AND DRAG CONFIGURATIONS

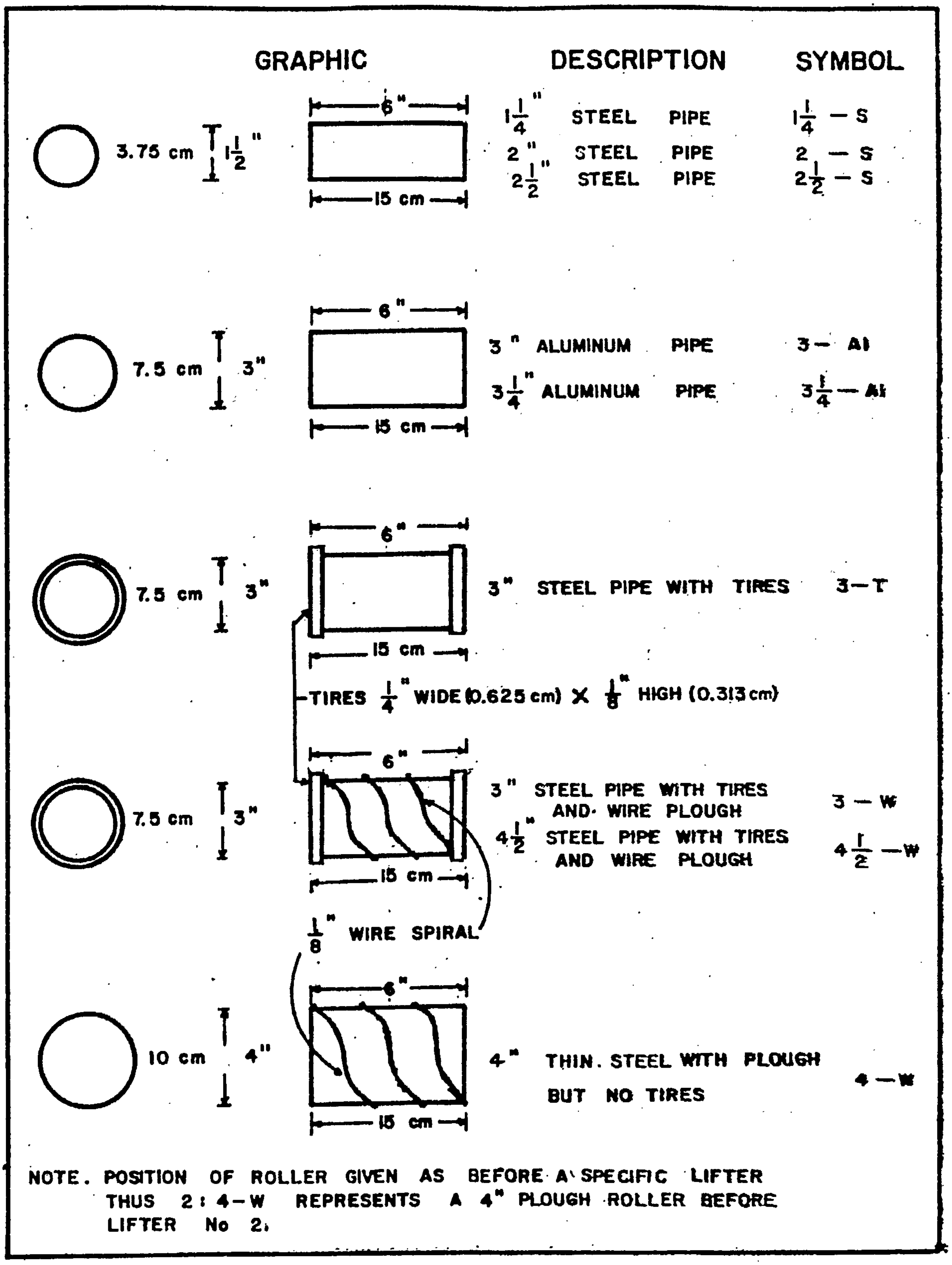

FIGURE 3. ROLLER TYPES

A typical deployment of rollers, lifters and drags is depicted in Figure 4.

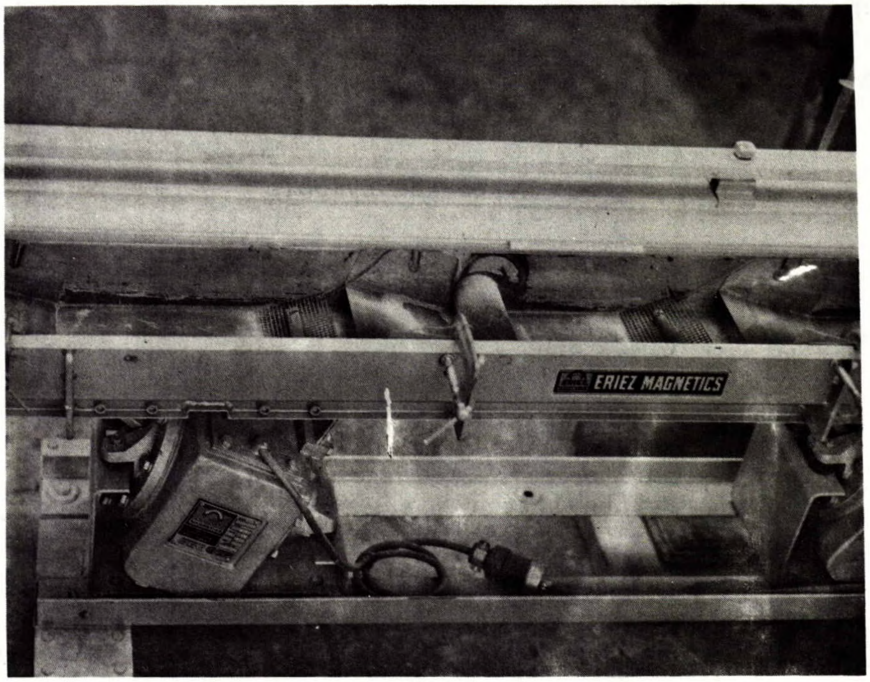

Figure 4. Rollers, Lifters and Drags

Experimental Details

The experimental drying trials performed were designed to cover a broad range of sizes, types of material, and degrees of wetness. They were more exploratory than systematic, the intent being to ascertain whether the method would fulfill the desired role.

Many of the trials were single runs, or only one traverse of the 10-ft (3-m) conveyor. As fineness of feed increased, and moisture content increased it was found necessary to double or treble the runs to achieve drying, in effect extending the system to 20 or 30 feet (6 or 9 m).

Details of all the trials performed are tabulated in decreasing order of feed size fineness, in Appendix A. Symbols have been used to cover the types of feed as shown in Table 1.

TABLE 1

Feed Types and Symbols

Type	Symbol
Sandstone	SS
Limestone	LS
Gravel	Gr
Unconsolidated Sand	S
Scheelite-Calcite	S-C
Barite	B
Pyrophyllite	P
Marl	M

Lifter configurations are indicated in Figure 2, roller types in Fig Figure 3. Heater height is the distance from the floor of the conveyor to the bottom of the reflector portion of the heater. Conveyor speed is given as per cent of the maximum possible. The degree of dryness is represented by the per cent moisture remaining in dried product.

It was found necessary to preheat the conveyor when working with fine, sticky feeds.

Results

The relationship between water eliminated and electric power consumed is summarized in Table 2.

TABLE 2

POWER REQUIREMENTS, PART I

RUN No.	FEED RATE lb/hr (kg/hr)	MOISTURE %	WATER REMOVED lb/hr (kg/hr)	POWER USED kWh/lb WATER REMOVED HEAT	CONVEY	TOTAL	kWh/lb SOLIDS DRIED
11	165(75)	2.9	4.93(2.24)	0.75	0.10	0.85	0.025
13	130(59)	3.0	4.03(1.83)	0.92	0.12	1.04	0.032
14	67(30.4)	3.4	2.35(1.07)	1.58	0.23	1.81	0.063
15	44(20.0)	4.6	2.12(0.96)	1.74	0.30	2.04	0.099
16	43(19.5)	4.6	2.07(0.94)	1.78	0.32	2.10	0.101
17	25(11.4)	7.4	2.00(0.91)	1.85	0.28	2.13	0.170
9	50(22.7)	4.6	2.41(1.10)	1.53	0.26	1.79	0.087
10	30(13.6)	7.4	2.40(1.09)	1.54	0.28	1.82	0.146
47	196(89)	1.9	3.80(1.73)	0.97	0.17	1.14	0.022
27	30(13.6)	8.5	2.17(0.99)	1.70	0.31	2.01	0.146
28-1	50(22.7)	8.5	3.16(1.44)	1.17	0.23	1.40	0.088
28-2	43(19.5)	2.9	1.49(0.68)	2.48	0.42	2.90	0.101
49-1	86(39.1)	8.3	3.93(1.78)	0.94	0.20	1.14	0.052
49-2	86(39.1)	4.3	3.48(1.58)	1.06	0.22	1.28	0.052
52-1	77(35.0)	8.2	3.66(1.66)	1.01	0.21	1.22	0.058
52-2	77(35.0)	4.0	2.96(1.34)	1.25	0.29	1.54	0.058
53-1	75(34.1)	8.6	2.26(1.03)	1.64	0.34	1.98	0.060
53-2	75(34.1)	6.0	4.12(1.87)	0.90	0.19	1.09	0.060
5	33(15.0)	4.6	1.53(0.70)	2.42	0.41	2.83	0.132
6	30(13.6)	4.6	1.43(0.65)	2.58	0.44	3.02	0.144
8	47(21.4)	4.6	2.27(1.03)	1.63	0.28	1.91	0.092
50	55(25.0)	4.7	2.68(1.22)	1.36	0.29	1.65	0.081
51	72(32.7)	4.7	3.38(1.54)	1.10	0.23	1.33	0.062
54	53(24.1)	5.1	2.75(1.25)	1.34	0.28	1.62	0.084
18	36(16.3)	3.8	1.42(0.65)	2.60	0.33	2.93	0.116
19	33(15.0)	4.5	1.55(0.71)	2.38	0.33	2.71	0.127
20	25(11.3)	7.4	1.99(0.91)	1.85	0.26	2.11	0.168
21-1	30(13.6)	10.0	3.00(1.36)	1.22	0.18	1.40	0.142
21-2	60(27.2)	1.0	0.61(0.28)	6.06	0.83	6.80	0.070
22-1	60(27.2)	10.0	3.04(1.38)	1.22	0.19	1.41	0.071
22-2	60(27.2)	5.7	2.65(1.20)	1.45	0.22	1.67	0.071
22-3	125(57)	1.6	2.04(0.93)	1.81	0.28	2.09	0.034
32	23(10.5)	7.4	1.61(0.73)	2.30	0.41	2.71	0.190
33	28(12.7)	7.4	1.96(0.89)	1.88	0.34	2.22	0.156
35-1	50(22.7)	7.4	2.63(1.19)	1.41	0.27	1.68	0.088
35-2	68(30.9)	2.7	1.88(0.86)	1.97	0.39	2.36	0.065
37-1	50(22.7)	8.9	2.08(0.95)	1.77	0.37	2.14	0.081
37-2	40(18.2)	5.3	2.25(1.02)	1.64	0.34	1.98	0.112
38-1	25(11.3)	10.1	2.19(1.00)	1.69	0.35	2.04	0.179
38-2	60(27.2)	2.4	1.47(0.67)	2.52	0.52	3.04	0.075
39-1	31(14.1)	9.8	1.81(0.82)	2.04	0.43	2.47	0.144
39-2	28(12.7)	4.8	1.35(0.61)	2.72	0.57	3.29	0.160
40-1	24(10.9)	9.9	2.23(1.01)	1.66	0.35	2.01	0.186
40-2	43(19.5)	2.0	0.79(0.36)	4.68	0.97	5.65	0.104
41-1	33(15.0)	9.6	2.62(1.19)	1.41	0.29	1.70	0.135
41-2	28(12.7)	2.6	0.72(0.33)	5.14	1.07	6.21	0.159
42-1	14.5(6.6)	13.8	0.12(0.05)	30.80	6.42	37.22	0.308
42-2	17.6(8.0)	12.4	2.44(1.11)	1.52	0.31	1.83	0.254
43-1	29(13.2)	13.0	1.16(0.53)	3.20	0.66	3.86	0.154
43-2	17.2(7.8)	9.9	1.77(0.80)	2.09	0.43	2.52	0.260

TABLE 2 (CONT)

POWER REQUIREMENTS, PART I

RUN No.	FEED RATE lb/hr (kg/hr)	MOISTURE %	WATER REMOVED lb/hr (kg/hr)	POWER USED			
				kWh/lb WATER REMOVED			kWh/lb SOLIDS DRIED
				HEAT	CONVEY	TOTAL	
44-1	46.5(21.1)	11.8	1.67(0.76)	2.22	0.46	2.68	0.096
44-2	46.5(21.1)	8.9	3.40(1.54)	1.09	0.23	1.32	0.096
44-3	35.2(16.0)	2.4	0.84(0.38)	4.40	0.92	5.32	0.127
45-1	47(21.4)	14.1	2.09(0.95)	1.78	0.37	2.15	0.095
45-2	47(21.4)	10.7	2.49(1.13)	1.49	0.31	1.80	0.095
45-3	47(21.4)	6.3	2.99(1.36)	1.23	0.26	1.49	0.095
46-1	52(23.6)	11.7	1.82(0.83)	2.03	0.42	2.45	0.086
46-2	52(23.6)	8.9	3.53(1.60)	1.05	0.22	1.27	0.086
46-3	52(23.6)	2.9	1.55(0.71)	2.42	0.50	2.92	0.086
48-1	42(19.1)	10.8	1.33(0.60)	2.78	0.58	3.36	0.106
48-2	71(32.3)	8.2	3.00(1.36)	1.24	0.26	1.50	0.063
48-3	71(32.3)	4.5	3.35(1.52)	1.10	0.23	1.33	0.063

The relationship between water elimination and power requirements is illistrated by Figure 5, which plots pounds per hour of water removed against kilowatts required to remove each pound of water. Power requirements are shown to decrease as the rate of removal, and hence the amount of water removed increases.

Water removal in relation to solids dried is shown in Figure 6. Power requirements per unit dried are shown to increase as moisture content increases up to 10 per cent moisture, but above 10 per cent results are erratic. At the same time, power required per pound of water removed is shown to decrease as the amount of water removed increases, thus conforming with the principle illustrated in Figure 5.

The power required per pound of solids treated is shown in Figure 7 to decrease as feed rate increases.

Figure 8 indicates that power per pound of water removed decreases as the percentage of moisture increases up to 10 per cent, after which it becomes erratic. This conforms with Figure 5. At the same time, power per pound of water removed is shown to decrease as feed rate increases.

The sequence of trials from No. 29 to No. 35 illustrates the use of drags and rollers to eliminate pellets.

The sequence, Nos. 45, 46, 48, attempts to study the effect of heater height. There does not seem to be a pattern either for water removed or for power consumed.

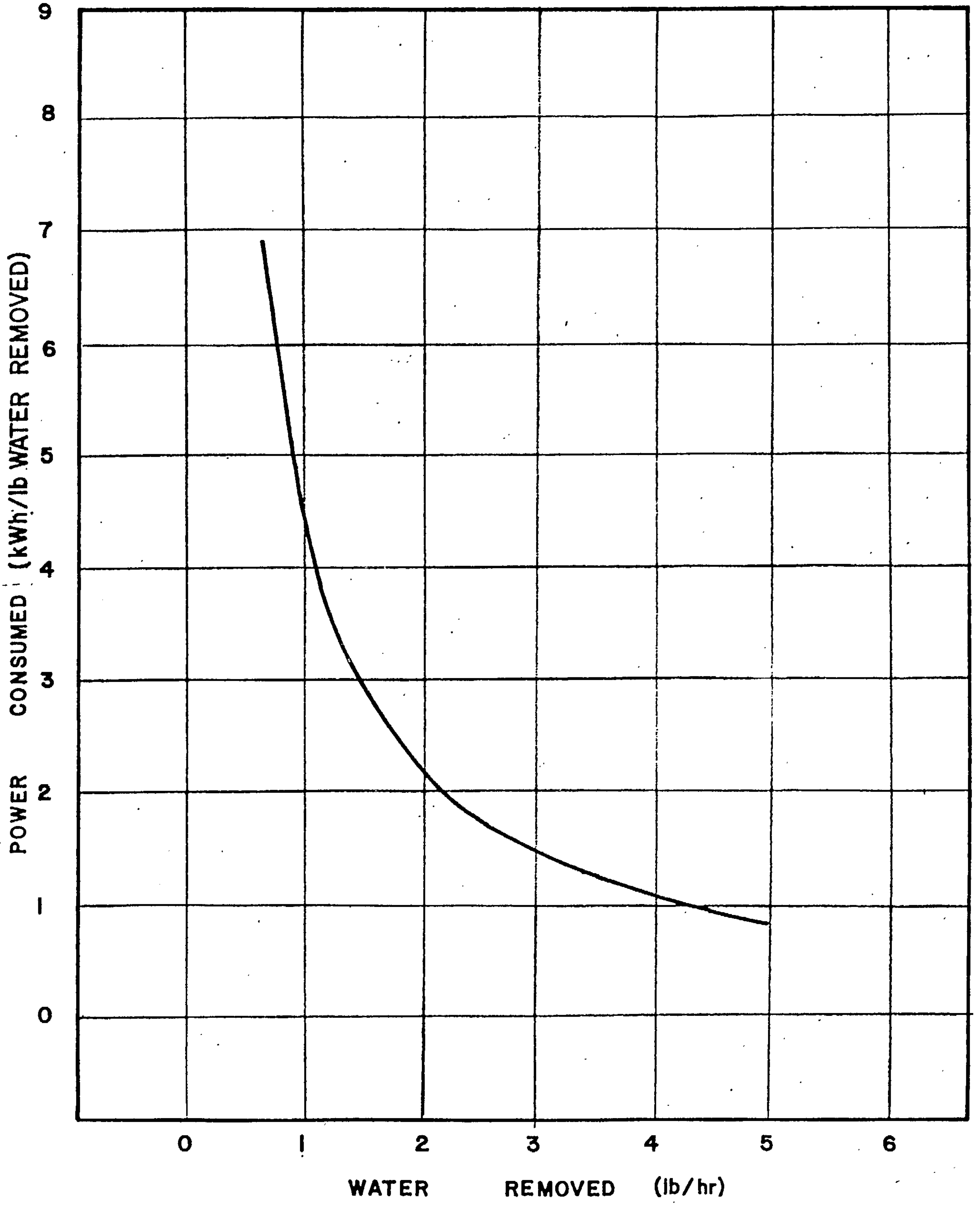

FIGURE 5. POWER REQUIRED TO REMOVE WATER

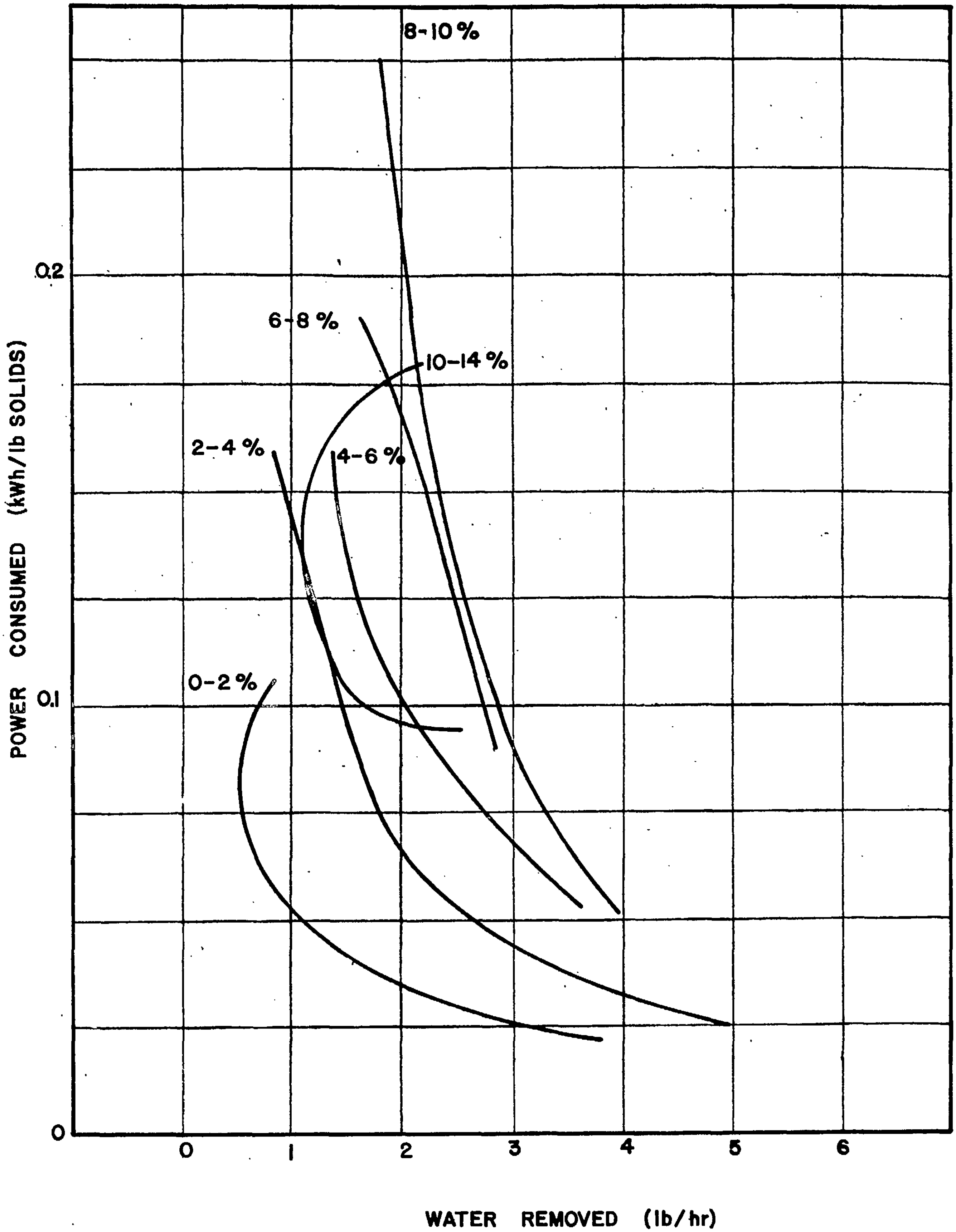

FIGURE 6. POWER PER POUND OF SOLIDS TO REMOVE WATER (VARIOUS MOISTURE CONTENTS, %)

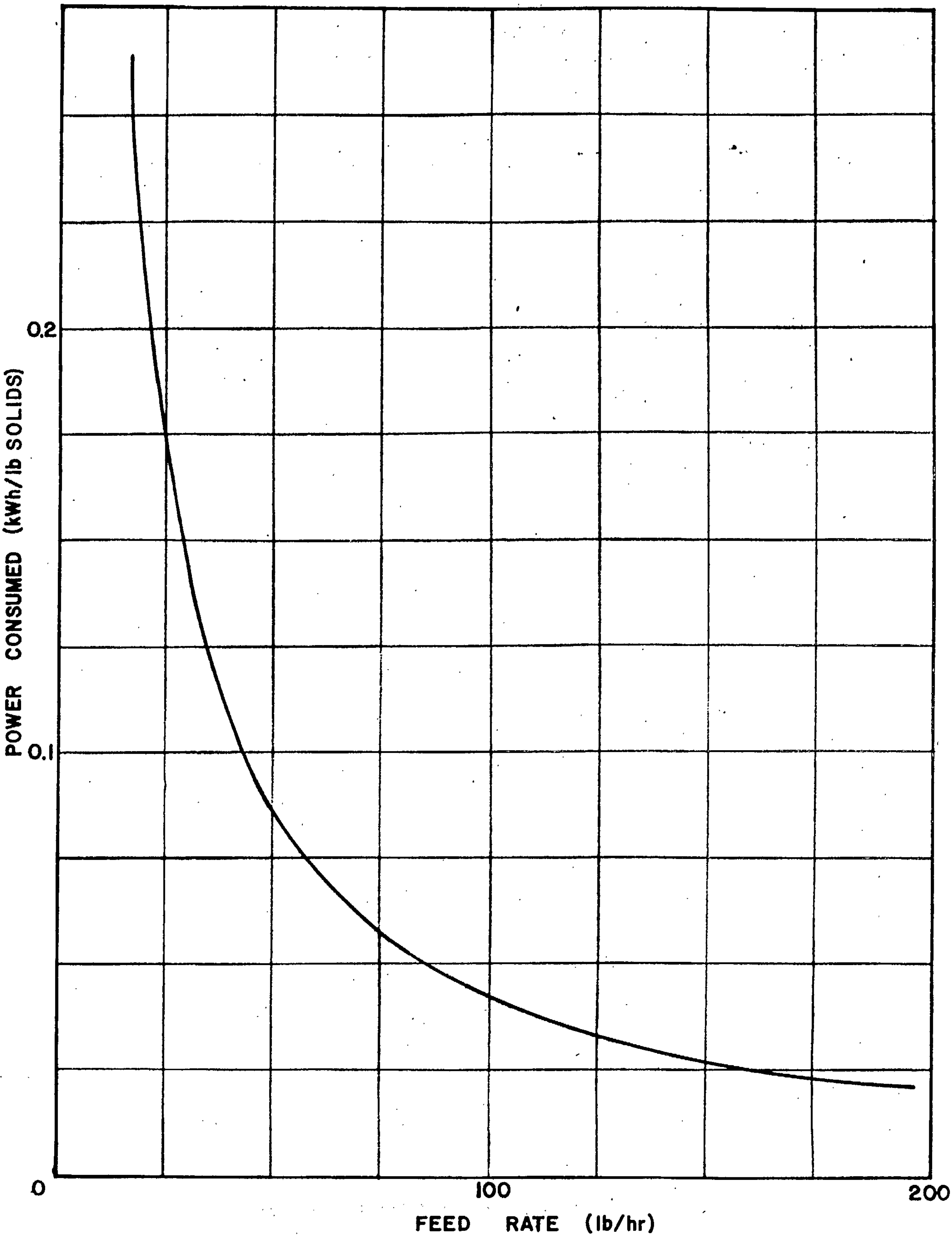

FIGURE 7. FEED RATE VS POWER PER POUND OF SOLIDS

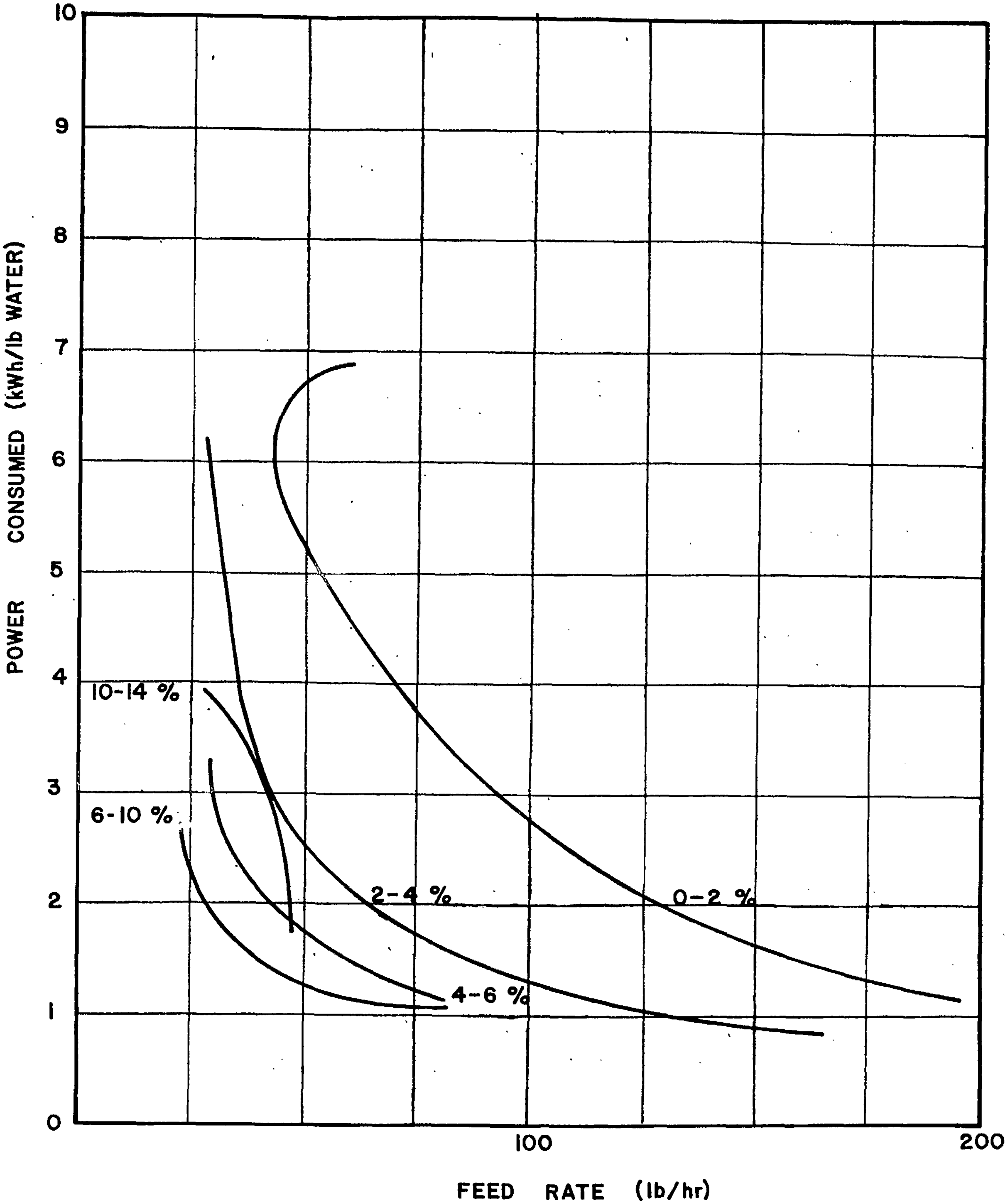

FIGURE 8. FEED RATE VS POWER CONSUMED
(VARIOUS MOISTURE CONTENTS, %)

Discussion

Considerable experience with the method was gained through the trials performed, and operation within the capabilities of the equipment was generally defined. There was no particular difficulty with the handling of granular, or lump materials. On the other hand, fine materials presented problems, particularly when the moisture content was high. These materials tended to cool the conveyor at the feed end and to build up. With moisture above a certain level, probably as entrained or capillary moisture rather than surface moisture, the vibration of the conveyor would release water from the feed to form a pool near the feed end, effectively stiffling the process. Sticky feeds would also coat rollers and lifters to produce erratic movement along the conveyor. The procedure which eventually was adopted for handling fine feed with high moisture involved an initial trial on the vibrating feeder. Any tendency for free water to vibrate out showed up at once, and that particular sample was rejected. Because different materials could retain different levels of moisture, the actual percentage of moisture could not be used as an indicator of this difficulty. However, if a feed could be moved by vibrating feeder it could usually be handled on the conveyor, provided the conveyor was preheated and the feed end kept up to temperature. Occasional sticking was loosened with a prod. Because such feeds tended to coat the rollers it proved best not to use rollers for the first traverse, but to accept pellets and lumps as part of the feed for the second traverse, and where necessary the third traverse. In these cases, the most effective reduction of pellets and lumps was achieved by placing a roller of 3-in. (7.5-cm) diameter equipped with a spiral of 1/8-in. (3.31-cm) wire (see Figure 3) ahead of lifter No. 2, with a heavier roller ahead of lifter No. 4.

An interesting comparison is provided in Table 3 between average results for 10, 20 and 30 feet (3, 6 and 9 m) of conveyer length..

TABLE 3

Results for Various Lengths of Conveyor

No. of Traverses	Conveyor length ft (m)	Average lb/hr water removed	Average kWh/lb water removed	Average kWh/lb solids dried
1	10 (3)	2.19	2.25	0.100
2	20 (6)	4.40	2.73	0.235
3	30 (9)	6.22	2.09	0.290

Table 3 shows that whereas the water removed and the power per pound of solids treated increased in proportion to conveyor length, the power per pound of water removed was erratic.

To derive a cost approximation, an arbitrary figure for power of 2.5c per kWh was assumed. On this basis a number of results, selected to be roughly representative of the whole program, were evaluated as shown in Table 4.

TABLE 4

Estimated Drying Cost - Part 1

Run No.	Size	Feed Rate lb/hr (Kg/hr)	Heater Height in. (cm)	Moisture %	Power Used (kWh)		Cost $/Ton
					Trial	Per Ton	
47	-4 mesh	196 (89)	6 (15)	1.9	4.34	23.8	0.60
13	1-½ in.	130 (59)	7 (17.5)	3.0	4.23	65	1.62
9	-4 mesh	50 (22.7)	7 (17.5)	4.6	4.33	173	4.33
27	-10 mesh	30 (13.6)	7 (17.5)	8.5	4.37	291	7.28
40-1	-28 mesh	24 (10.9)	7 (17.5)	9.9	4.47	372	9.30
32	-28 mesh	23 (10.4)	7 (17.5)	7.4	4.29	373	9.35
42-2	-65 mesh	17.6 (8.0)	7 (17.5)	12.4	4.47	507	12.68
Totals		470.6 (213.6)				1804.8	45.16
Average		67 (30.5)				258	6.45
Av. all trials						200	5.00

Part 1 trials demonstrated that the method had advantages for the type of service required by the Section and improvements, based on this experience, were planned.

PART 2

Description of Equipment

The improved unit had two components - conveyor and heaters.

Because the 6-in. (15-cm) conveyor used in Part 1 had proven too low in capacity, and even tended to block by bridging with 2-in. (5-cm) feed, a similar but larger conveyor was used for the Part 2 experiments. The length, 10 ft (3 meters), was the same, but the width was 8 in. (20 cm) and the sides 4 in. (10 cm). This trough was mounted on four equally spaced 45A vibratory drives fastened to a common base. The vibrating speed was variable by means of a voltage controller with a scale of 0 to 120.

"Solar" radiant panels were obtained from P.M. Wright Electrical Co., Ltd. Each panel was 8 in. by 12 in. (20 by 30 cm) in size so that 10 panels placed end to end covered an area exactly equal to that of the conveyor bottom. These were suspended over the conveyor on a Dexion frame and so mounted that the distance from conveyor bottom to panel face was adjustable. The panels operated at 550 volts with a total power rating of 26.8 Kw.

The patented feature of "Solar" radiant heating panels is a fused-quartz facing. The wavelength of infrared radiation emitted by these facings covers a range from about 2.5 to 5.5 μm, depending upon surface temperature. This relationship is indicated by Figure 9. An advantage for moisture evaporation from mineral surfaces is said to be that thin layers of water absorb high levels of infrared radiation. The penetration at these wavelengths is also good, so that a bed of material is rapidly heated throughout, and agglomerates are heated both inside and on the surface.

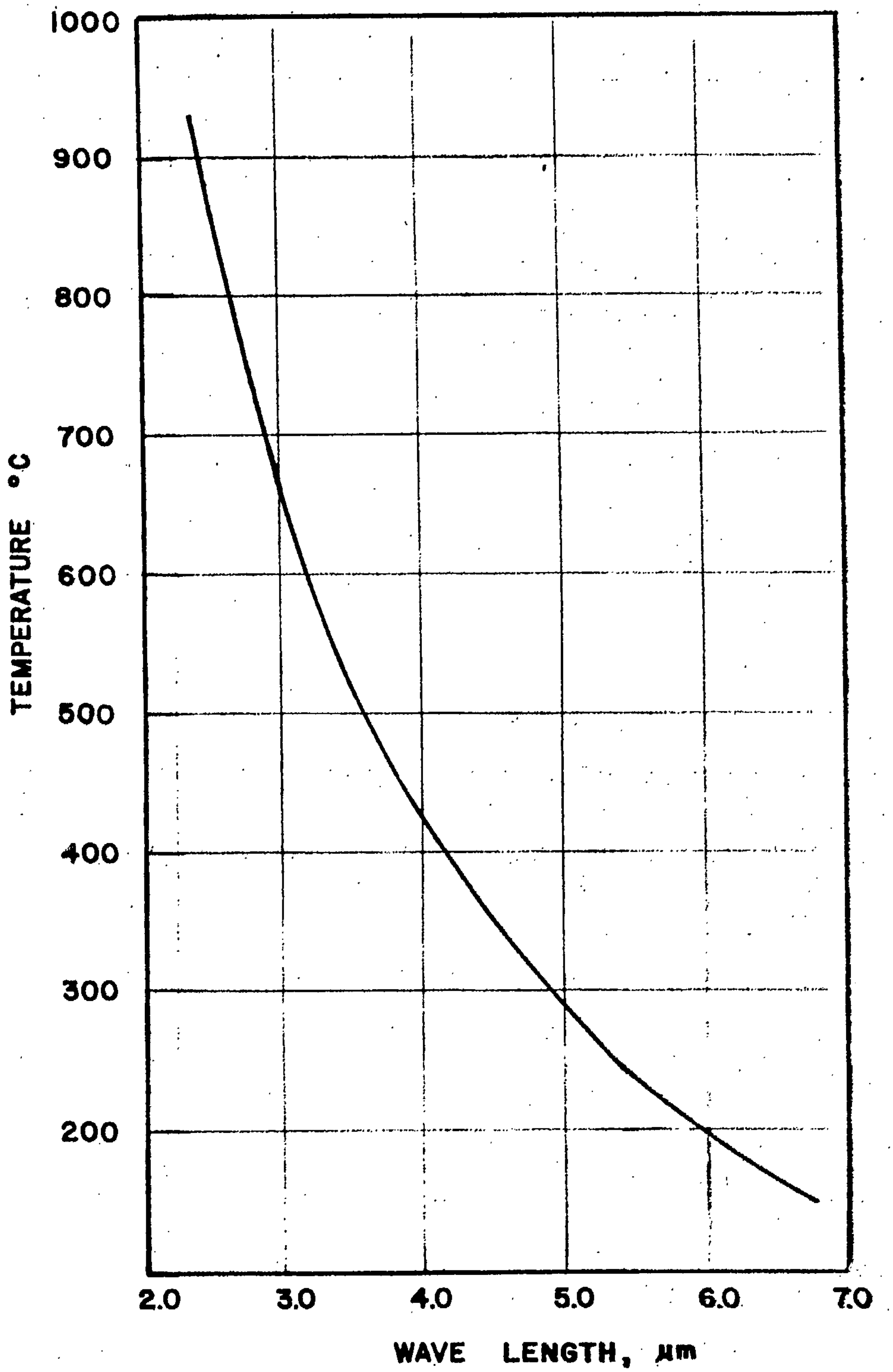

FIGURE 9. RELATIONSHIP OF WAVE LENGTH TO TEMPERATURE OF 'SOLAR' PANELS

High level was again controlled by means of per cent active timing, and during the trials continuous heating was used, i.e. 100 per cent active.

The same Jeffrey feeder employed in the Part 1 experiments was used for Part 2.

Figure 10 is a general view of this drying unit.

A system of lifters, similar to those employed for Part 1 experiments, was also used for Part 2. The configurations tried are illustrated in Figure 11. Trials were also made with drags and rollers in a similar way to Part 1 usage (see Figure 4), but because of the altered conditions, it was found that only 3-in. (7.5-cm) aluminum rollers were required. When used, these were placed before lifters No. 2 and No. 3 only.

Because the heat developed in the system affected the conveyor vibrators, it was found necessary to protect them with asbestos pads and to cool them with compressed air jets.

Experimental Details

Following the experience gained through Part 1 experiments an attempt was made to systematize the work of Part 2. The experimental program included establishing the conveyor transporting capacity and determining characteristic heating curves for the system, as well as controlled drying trials.

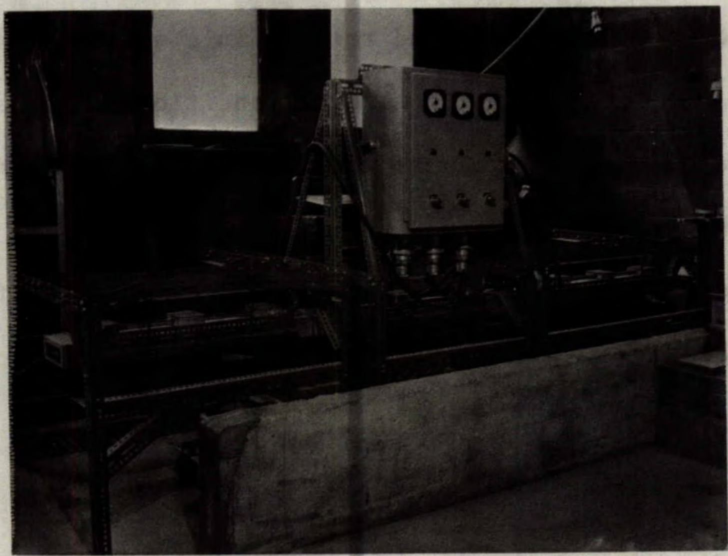

Figure 10. Second Drying Unit.

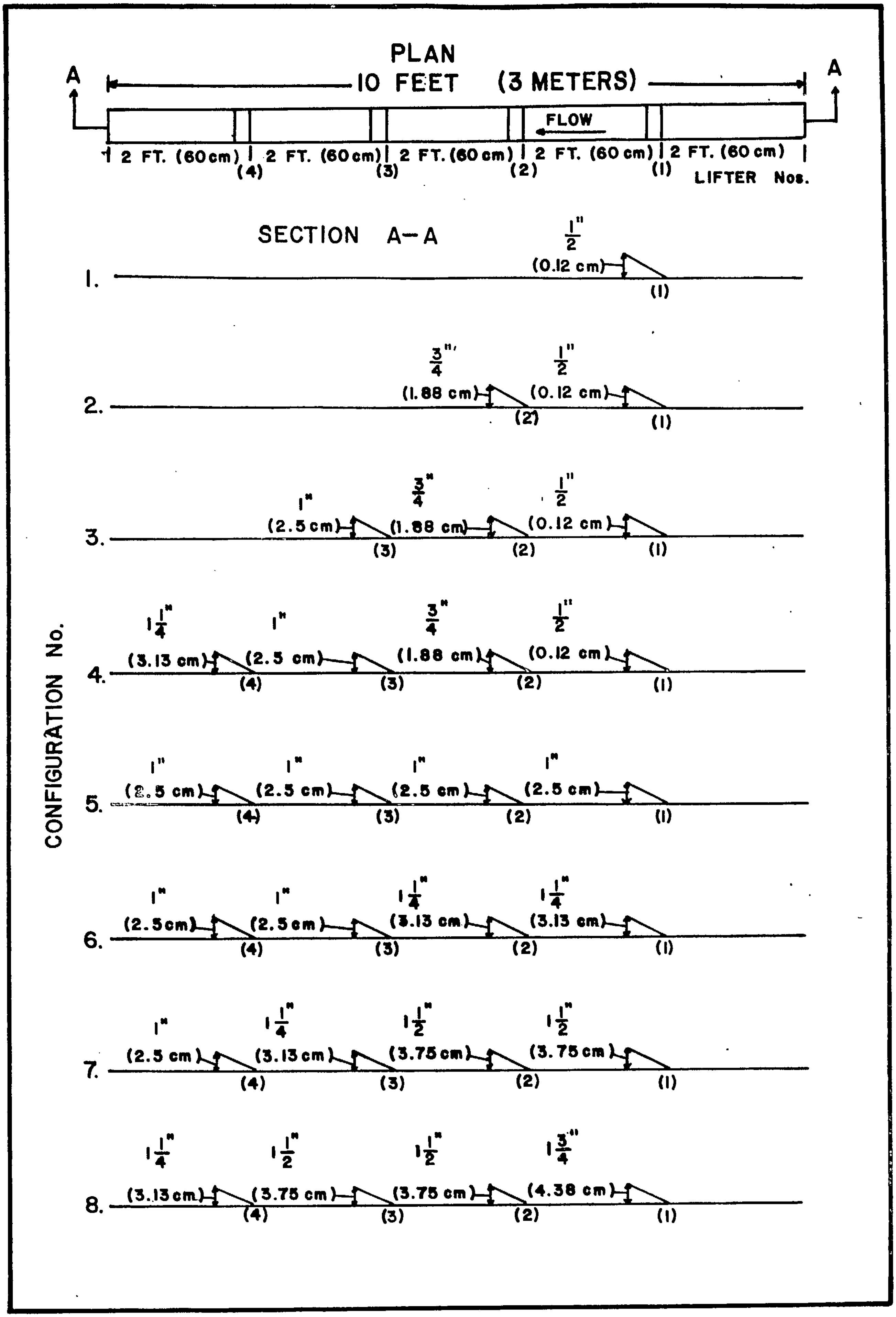

FIGURE 11. LIFTER CONFIGURATIONS, PART 2

Transporting adequacy was established for the conveyor by ascertaining the weights of dry, sized, quartz sand discharged at selected controller settings. Figure 12 indicates the results.

The effect of distance between the face of the Solar panels and the top of the bed of material to be heated is shown in Figure 13. The data were obtained by static testing; the bulb of a thermometer was located at the 1-in. (2.5-cm) level of a 2-in. (5.0-cm) bed of sand sitting on the conveyor trough, but not in motion, and temperatures were read every five minutes. The 50% active level was used to remain within the maximum of the chemical thermometer used.

The same method was used to ascertain the effect of per cent active time for heating. Figure 14 shows this for a 4-in. (10-cm) heater to top of bed distance and Figure 15 for 6 in. (15 cm). In subsequent testing the 6-in. (15-cm) clearance was most frequently used, although higher heat concentration is shown for the 4-in. (10-cm) clearance. With 4 in. (10 cm) clearance the heater is close to the top of the conveyor sides, allowing very little observation of the bed of material being treated. Moreover, for most cases, the heat generated at 4-in. (10-cm) clearance is greater than required for adequate drying.

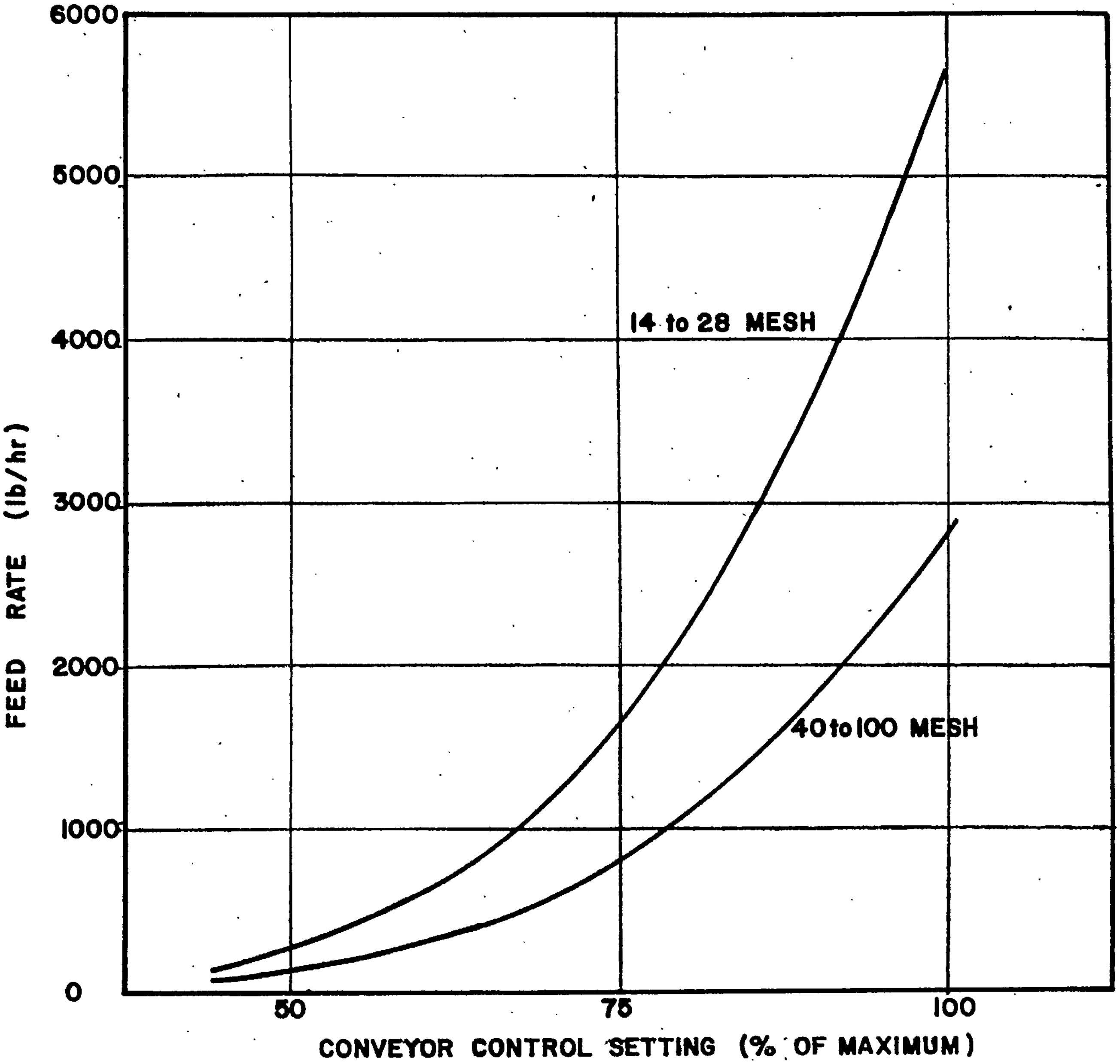

FIGURE 12. CONVEYOR CAPACITY, DRY SOLIDS

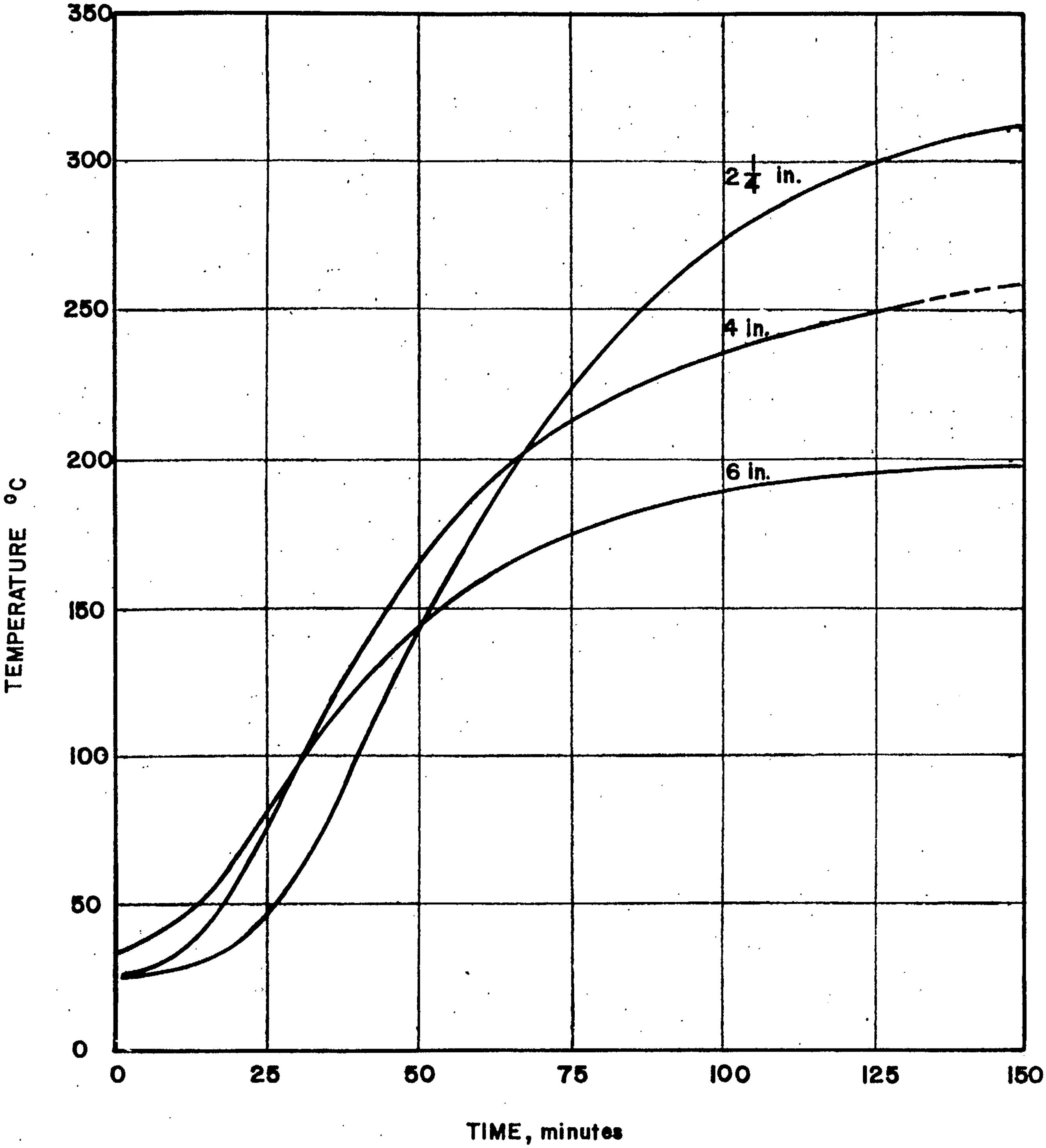

FIGURE 13. HEATING CURVES, 50 % ACTIVE, 14- to 28-MESH SAND (VARIOUS SAND TO HEATER DISTANCES)

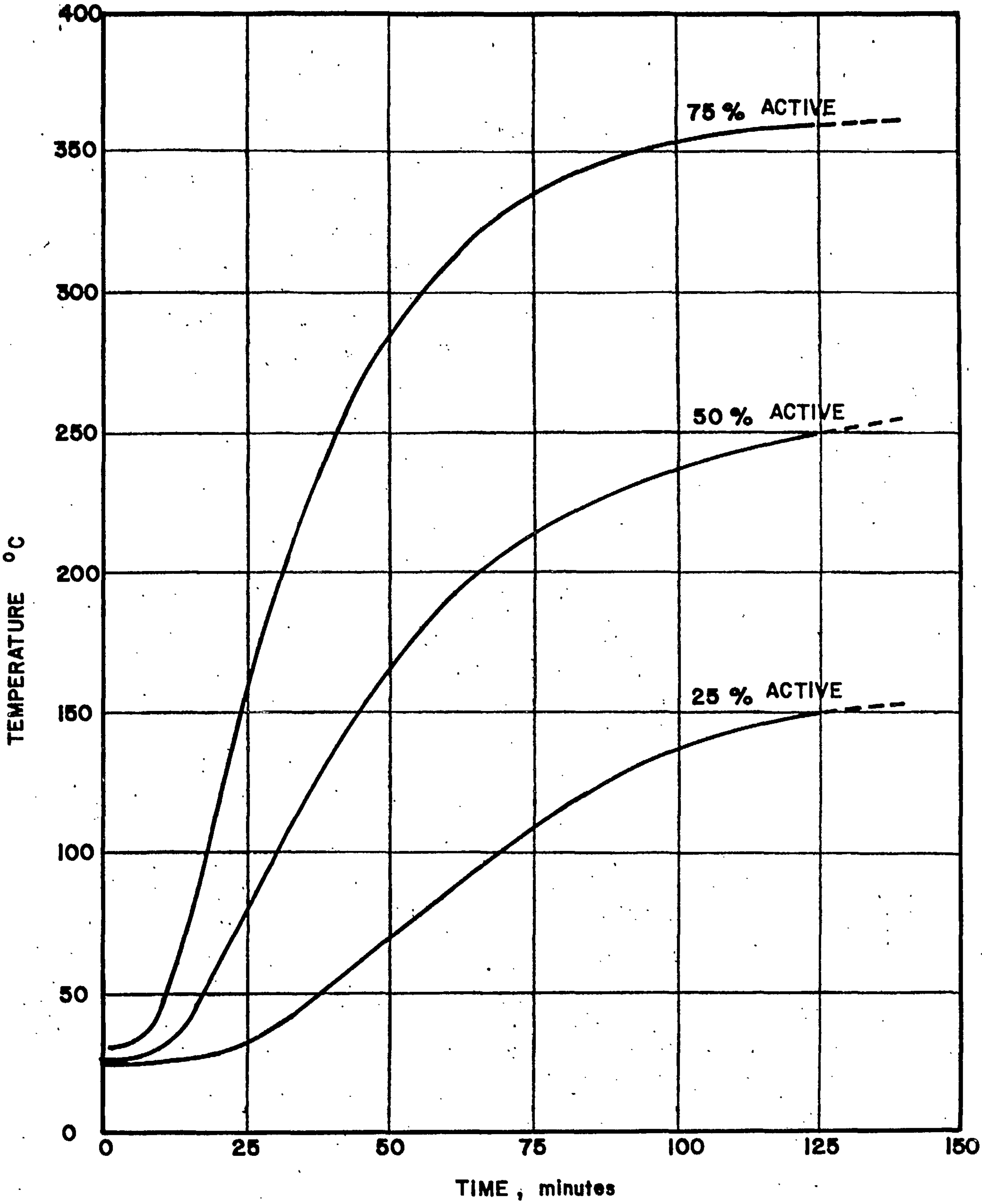

FIGURE 14. HEATING CURVES, 4 - IN. CLEARANCE, 14-to 28-MESH SAND
(VARIOUS ACTIVE HEATING TIMES)

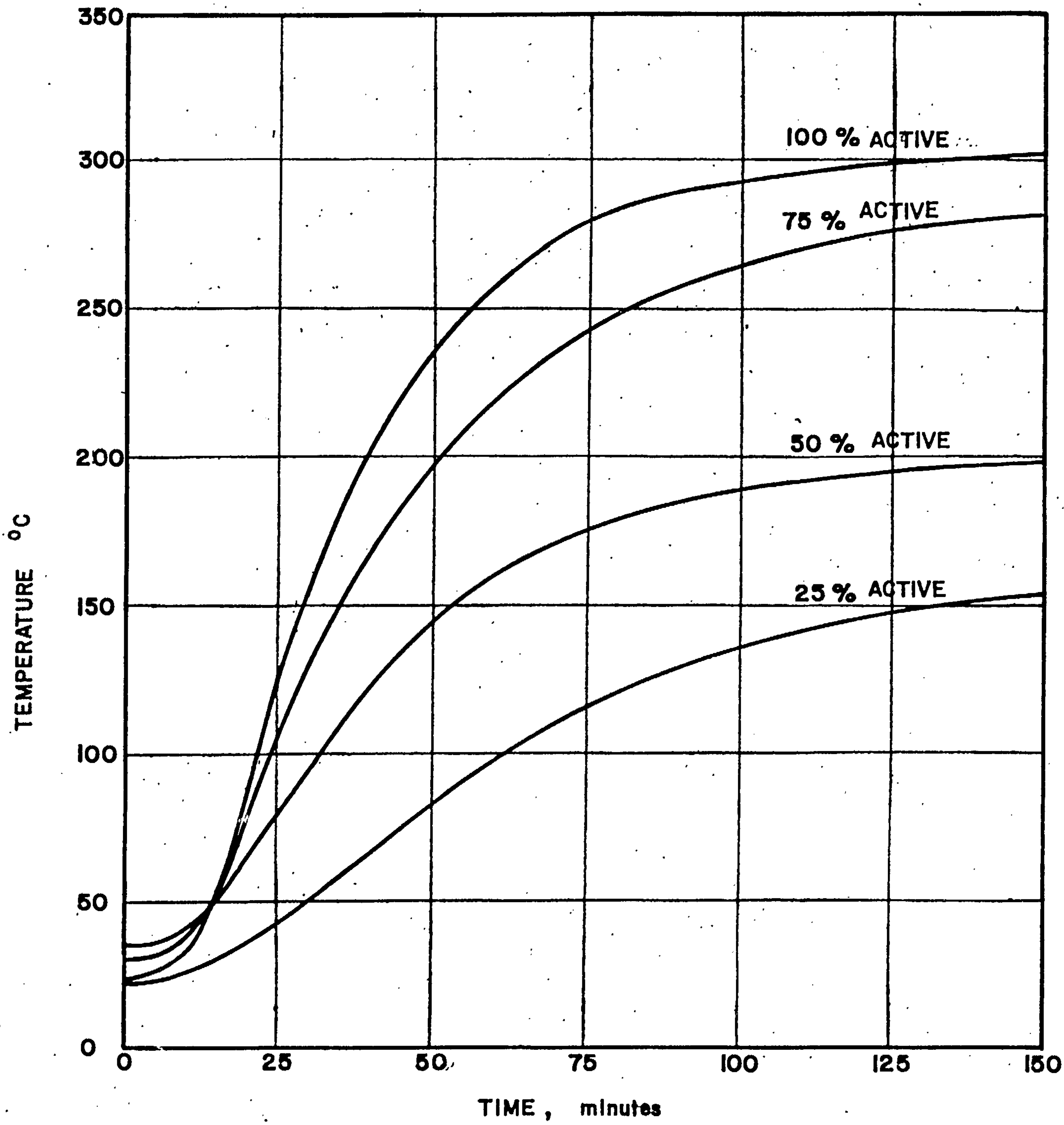

FIGURE 15. HEATING CURVES, 6-IN. CLEARANCE 14-to 28-MESH SAND (VARIOUS ACTIVE HEATING TIMES)

The drying experiments were laid out to explore various effects at four levels of moisture content, 2.5, 5.0, 7.5 and 10.0 per cent. The effect of lifters was particularly examined, because opening up the bed and allowing steam to escape was shown in Part 1 to be particularly pertinent. The effect of drags was also examined. This work was done with a relatively easy-to-dry standard material, 28- to 100-mesh quartz sand. Trials with various sizes of feed were also made, and trials with very difficult materials. It was only where pellets formed that rollers were found necessary.

All trials performed are summarized in Appendix B.

Results

The relationship between water eliminated and electric power consumed for Part 2 experiments is summarized in Table 5.

TABLE 5

POWER REQUIREMENTS, PART 2

RUN No.	FEED RATE lb/hr (kg/hr)	MOISTURE %	WATER REMOVED lb/hr (kg/hr)	POWER USED: kWh/lb WATER REMOVED			
				HEAT	CONVEY	TOTAL	kWh/lb SOLIDS DRIED
7	225 (102)	2.5	6.54 (2.97)	4.10	0.09	4.19	0.107
8	225 (102)	2.5	6.54 (2.97)	4.10	0.10	4.20	0.108
9	180 (82)	5.0	9.48((4.30)	2.82	0.06	2.88	0.146
10	194 (88)	5.0	10.22 (4.65)	2.62	0.07	2.69	0.141
11	112 (51)	7.5	9.08 (4.13)	2.95	0.06	3.01	0.244
12	112 (51)	7.5	9.08 (4.13)	2.95	0.07	3.02	0.245
13	86 (39)	10.0	9.60 (4.36)	2.79	0.06	2.85	0.318
14	210 (95.5)	2.5	5.38 (2.44)	4.98	0.09	5.07	0.130
15	255 (116)	2.5	6.53 (2.97)	4.10	0.09	4.19	0.107
16	269 (122)	2.5	6.89 (3.13)	3.89	0.10	3.99	0.102
17	172 (78)	5.0	9.06 (4.11)	2.96	0.05	3.01	0.158
18	180 (82)	5.0	9.48 (4.30)	2.83	0.06	2.89	0.152
19	158 (72)	7.5	12.80 (5.82)	2.09	0.04	2.13	0.172
20	158 (72)	7.5	12.80 (5.82)	2.09	0.05	2.14	0.173
21	90 (41)	10.0	10.00 (4.55)	2.68	0.06	2.74	0.304
22	82 (37)	10.0	9.10 (4.13)	2.94	0.07	3.01	0.335
23	359 (163)	2.5	9.20 (4.18)	2.92	0.05	2.97	0.076
24	322 (146)	2.5	8.27 (3.76)	3.24	0.07	3.31	0.085
25	330 (150)	2.5	8.46 (3.84)	3.17	0.08	3.25	0.083
26	210 (95.5)	5.0	11.07 (5.02)	2.42	0.04	2.46	0.130
27	195 (89)	5.0	10.26 (4.67)	2.61	0.06	2.67	0.140
28	210 (95.5)	5.0	11.07 (5.02)	2.42	0.06	2.46	0.130
29	150 (68)	7.5	12.18 (5.53)	2.20	0.04	2.24	0.182
30	135 (61)	7.5	10.95 (4.98)	2.45	0.05	2.50	0.202
31	135 (61)	7.5	10.95 (4.98)	2.45	0.06	2.51	0.203
32	105 (48)	10.0	11.68 (5.31)	2.29	0.04	2.33	0.260
33	97 (44)	10.0	10.78 (4.90)	2.49	0.05	2.54	0.282
34	135 (61)	10.0	15.00((6.82)	1.78	0.04	1.82	0.204
35	410 (186)	2.5	10.51 (4.78)	2.55	0.05	2.60	0.067
36	410 (186)	2.5	10.51 (4.78)	2.55	0.06	2.61	0.067
37	195 (89)	5.0	10.52 (4.78)	2.54	0.05	2.59	0.140
38	254 (115)	5.0	13.37 (6.08)	2.00	0.05	2.05	0.108
39	172 (78)	7.5	13.92 (6.33)	1.92	0.04	1.96	0.159
40	225 (102)	7.5	18.25 (8.30)	1.47	0.04	1.51	0.122
41	105 (48)	10.0	11.67 (5.31)	2.30	0.04	2.34	0.260
42	120 (54.5)	10.0	13.32 (6.07)	2.01	0.04	2.05	0.228
43	562 (244)	2.5	14.40 (6.55)	1.86	0.03	1.89	0.048
44	450 (204)	2.5	11.50 (5.23)	2.33	0.05	2.38	0.061
45	480 (218)	2.5	12.30 (5.60)	2.18	0.05	2.23	0.057
46	278 (126)	5.0	14.67 (6.67)	1.83	0.03	1.86	0.098
47	270 (122.5)	5.0	14.22 (6.46)	1.89	0.05	1.94	0.102
48	210 (95.5)	7.5	17.00 (7.72)	1.57	0.03	1.60	0.130
49	210 (95.5)	7.5	17.00 (7.72)	1.57	0.04	1.61	0.131
50	150 (68)	10.0	16.67 (7.57)	1.61	0.03	1.64	0.182
51	143 (65)	10.0	15.90 (7.22)	1.69	0.04	1.73	0.192
52	225 (102)	5.0	11.82 (4.92)	2.27	0.05	2.32	0.121
53	254 (115)	5.0	13.37 (6.07)	2.00	0.05	2.05	0.108
54	225 (102)	5.0	11.82 (4.92)	2.27	0.05	2.32	0.121
55	240 (109)	5.0	12.65 (5.75)	2.12	0.05	2.17	0.114
56	169 (77)	7.5	13.70 (6.22)	1.95	0.03	1.98	0.161

TABLE 5 (CONT)
POWER REQUIREMENTS, PART 2

RUN No.	FEED RATE lb/hr (kg/hr)	MOISTURE %	WATER REMOVED lb/hr (kg/hr)	POWER USED kWh/lb WATER REMOVED HEAT	CONVEY	TOTAL	kWh/lb SOLIDS DRIED
57	139 (63)	7.5	11.28 (5.13)	2.37	0.06	2.43	0.198
58	150 (68)	7.5	12.18 (5.54)	2.20	0.04	2.24	0.181
59	142 (64.5)	7.5	11.52 (5.24)	2.33	0.05	2.38	0.192
60	135 (61.5)	7.5	10.93 (4.97)	2.45	0.06	2.52	0.203
61	157 (71.5)	7.5	12.71 (5.78)	2.11	0.05	2.16	0.174
62	157 (71.5)	7.5	12.71 (5.78)	2.11	0.04	2.15	0.173
63	112 (51)	5.0	55.88 (2.67)	4.56	0.08	4.64	0.243
64	75 (34)	5.0	3.94 (1.79)	6.80	0.15	6.95	0.364
65	68 (31)	5.0	3.58 (1.62)	7.50	0.19	7.69	0.404
66	120 (54.5)	5.0	6.32 (2.86)	4.24	0.08	4.32	0.227
67	108 (49)	5.0	5.67 (2.58)	4.72	0.10	4.82	0.253
68	105 (48)	5.0	5.53 (2.51)	4.85	0.12	4.97	0.261
69	127 (58)	5.0	6.68 (3.02)	4.02	0.07	4.09	0.214
70	116 (53)	5.0	6.11 (2.78)	4.39	0.09	4.48	0.236
71	157 (71.5)	5.0	8.27 (3.76)	3.23	0.06	3.29	0.174
72	150 (68)	5.0	7.89 (3.58)	3.40	0.07	3.47	0.182
73	187 (85)	5.0	9.84 (4.45)	2.72	0.05	2.77	0.146
74	180 (82)	5.0	9.45 (4.30)	2.84	0.06	2.90	0.152
75	199 (90.5)	5.0	10.47 (4.77)	2.56	0.05	2.61	0.137
76	180 (82)	5.0	9.45 (4.30)	2.84	0.06	2.90	0.152
77	232 (105)	5.0	12.47 (5.56)	2.15	0.04	2.19	0.118
78	218 (99)	5.0	11.48 (5.22)	2.34	0.05	2.39	0.125
79	247 (112)	5.0	13.00 (5.91)	2.06	0.04	2.10	0.110
80	218 (99)	5.0	11.48 (5.22)	2.34	0.05	2.39	0.125
81	255 (116)	5.0	13.44 (6.11)	1.99	0.04	2.03	0.107
82	243 (110)	5.0	12.77 (5.81)	2.09	0.05	2.14	0.112
83	200 (91)	5.0	10.52 (4.79)	2.54	0.05	2.59	0.136
84	273 (124)	5.0	14.37 (6.53)	1.86	0.04	1.90	0.100
85	600 (272.5)	2.6	16.00 (7.37)	1.67	0.03	1.70	0.046
86	300 (136)	7.5	24.38 (11.05)	1.10	0.02	1.12	0.091
87	150 (68)	7.5	12.15 (5.52)	2.20	0.04	2.24	0.182
88	188 (85.5)	7.5	15.27 (6.95)	1.76	0.03	1.79	0.145
89	200 (91)	5.0	10.52 (4.79)	2.54	0.05	2.59	0.137
90	100 (45.5)	14.3	16.70 (7.60)	1.60	0.03	1.63	0.272
91-1	24 (10.9)	13.7	0.90 (0.41)	29.80	0.51	30.31	1.134
91-2	55 (25)	10.9	6.62 (3.01)	4.05	0.07	4.12	0.496
92-1	75 (34)	14.3	9.75 (4.42)	2.75	0.06	2.81	0.366
92-2	63 (28.5)	3.5	2.22 (1.01)	12.06	0.21	12.27	0.432
93-1	100 (45.5)	9.7	8.77 (3.98)	3.06	0.06	3.12	0.274
93-2	200 (91)	1.6	3.05 (1.38)	8.79	0.09	8.88	0.138
94-1	60 (27)	18.6	10.54 (4.79)	2.54	0.05	2.59	0.456
94-2	60 (27)	5.0	2.80 (1.27)	9.58	0.16	9.74	0.454
95-1	54 (24.5)	37.1	15.90 (7.24)	1.68	0.03	1.71	0.507
95-2	36 (16.5)	22.1	9.50 (4.32)	2.82	0.04	2.86	0.755

The relationship between water eliminated and power requirements is shown in Figure 16. Compared with Part 1 results (Figure 5), much greater efficiency was achieved with the Part 2 equipment.

Water removed in relation to solids dried is shown in Figure 17. Compared with those of Figure 6, the curves and spacing are more regular, reflecting improved control. The greater efficiency of water removal over Part 1 is further demonstrated.

Power required per pound of solids treated is shown in Figure 18. Compared with the results shown in Figure 7, a much higher drying rate per unit of power was achieved in Part 2.

Figure 19 shows power required to remove water in relation to feed rate. Again, marked improvement is noted for the Part 2 trials. (Compare with Figure 8).

Trials No. 7 to 42 studied the effect of lifters on drying rate. Four levels of water content, 2.5 to 10.0 per cent moisture, were examined at three different traverse speeds using 28- to 100-mesh quartz sand. The heater-to-bed distance was kept constant at 6 in. (15 cm). This work is summarized in Table 6.

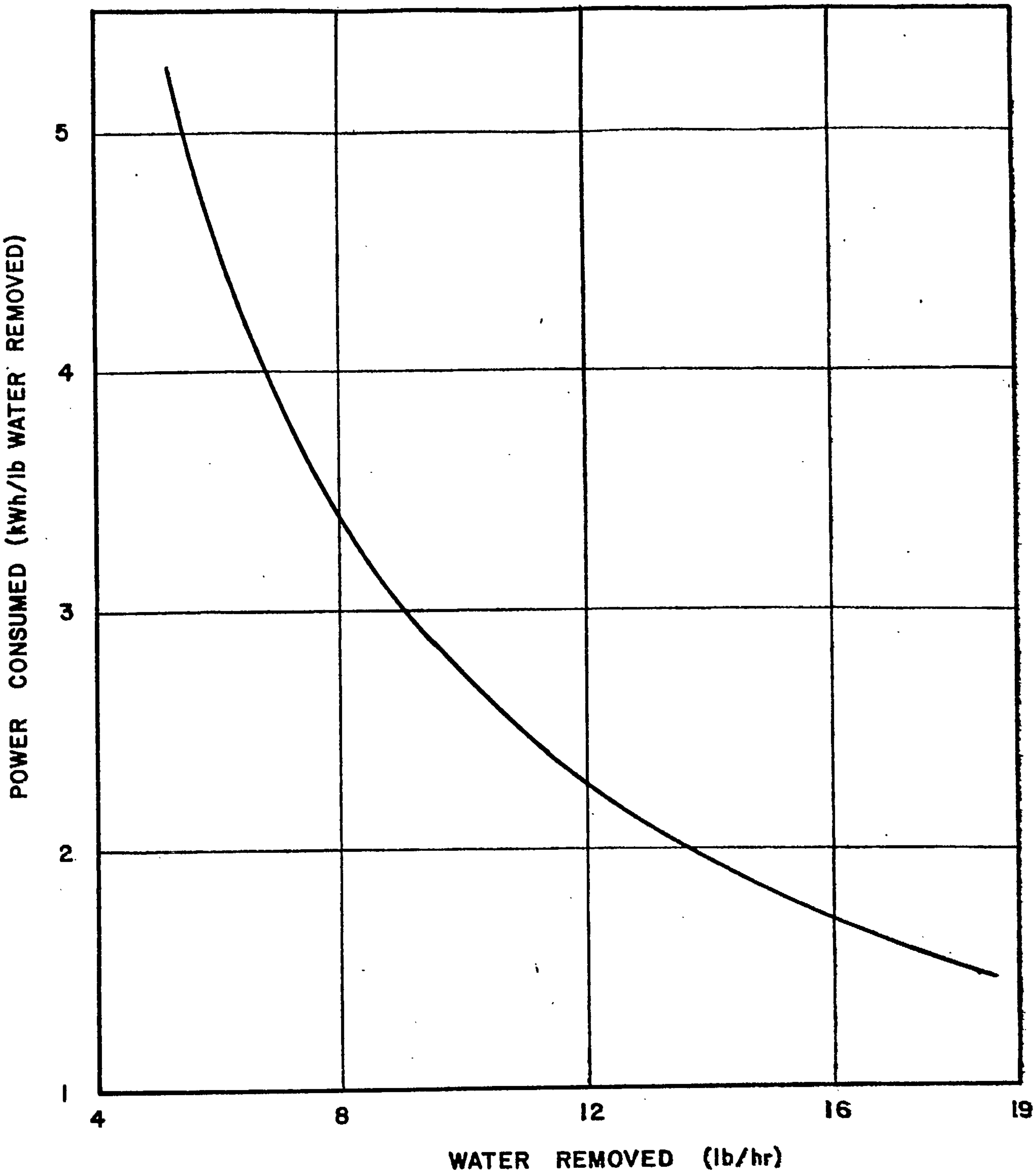

FIGURE 16. POWER REQUIRED TO REMOVE WATER

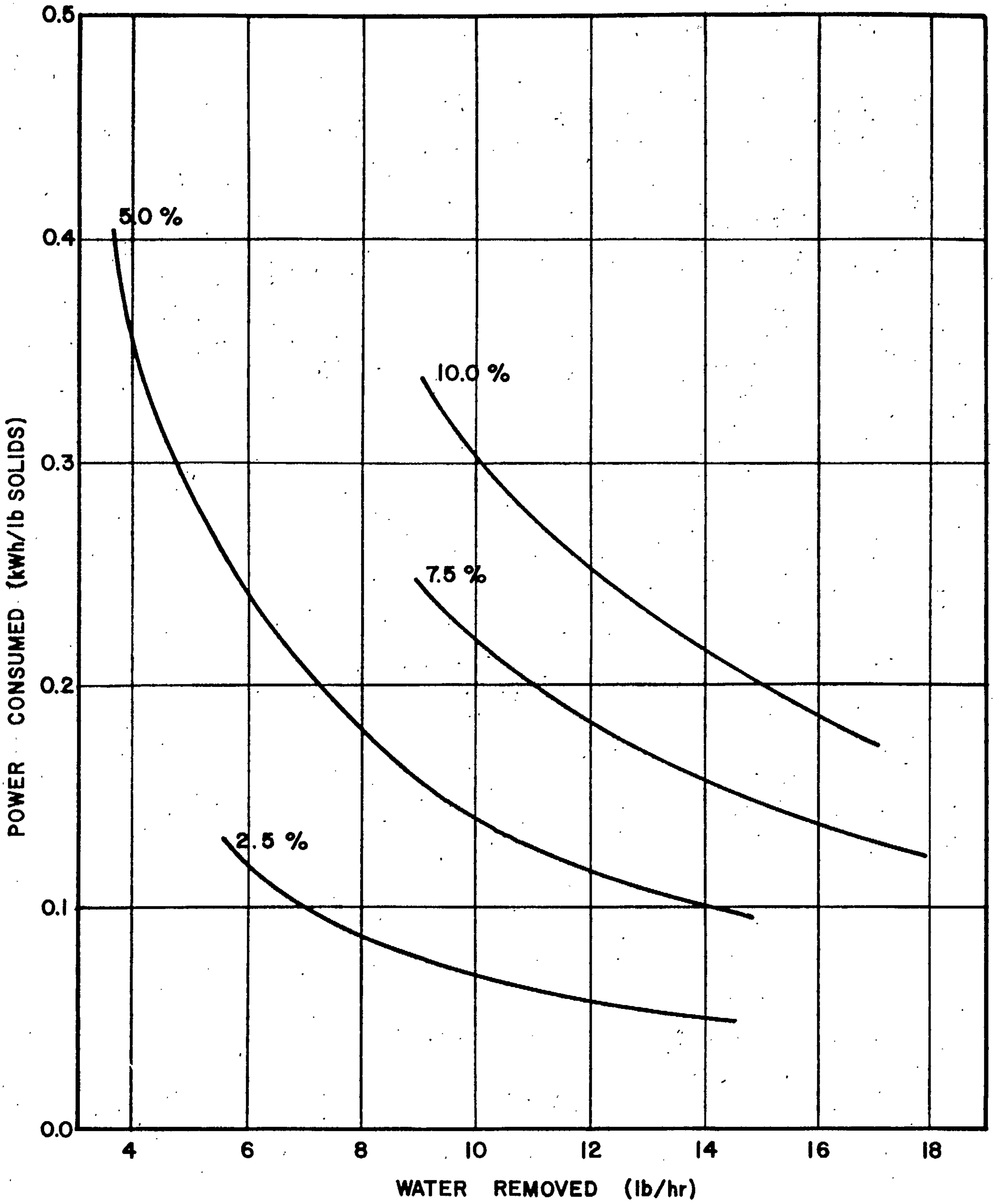

FIGURE 17. POWER PER POUND OF SOLIDS TO REMOVE WATER (VARIOUS MOISTURE CONTENTS, %)

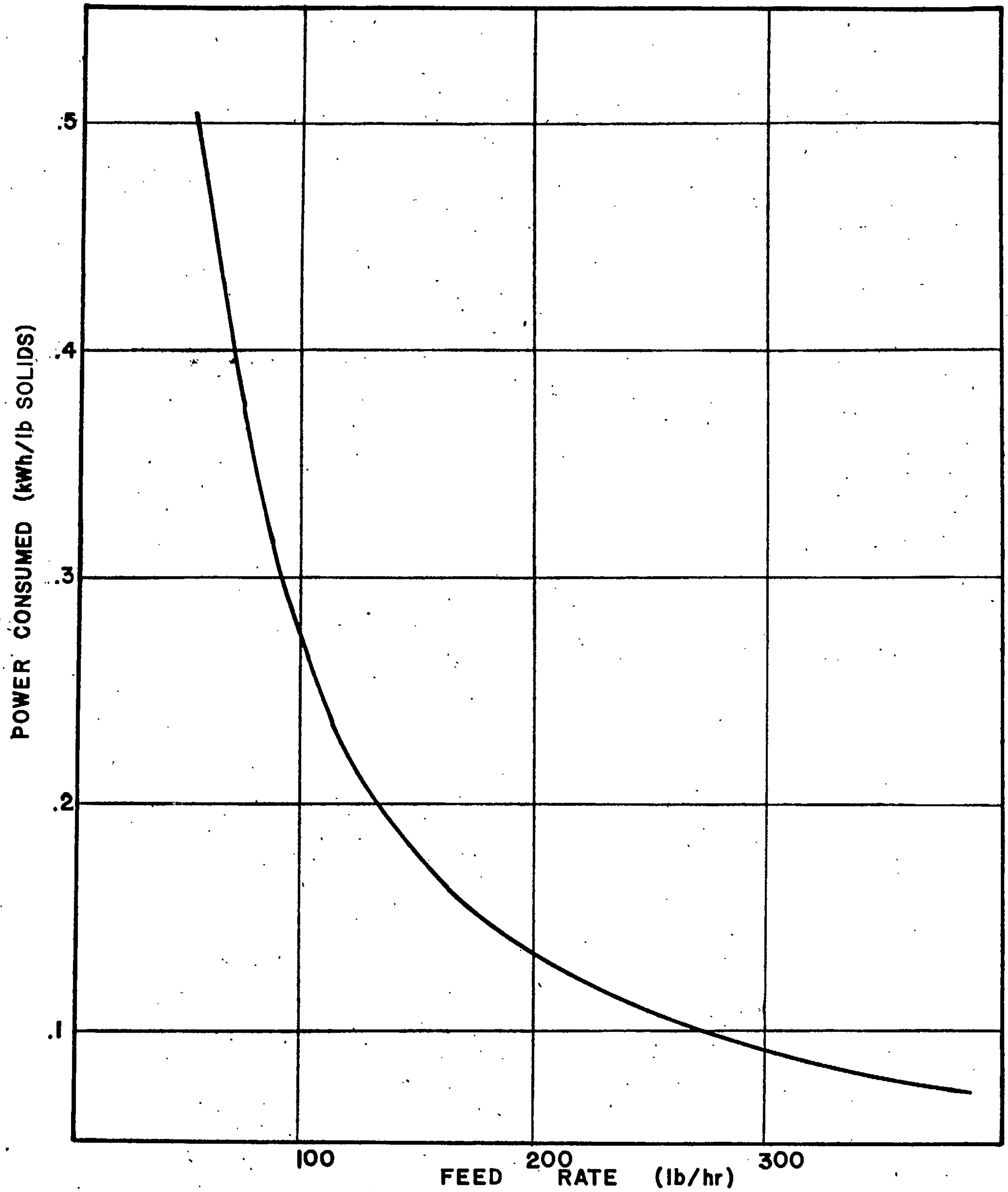

FIGURE 18. FEED RATE VS POWER PER POUND OF SOLIDS

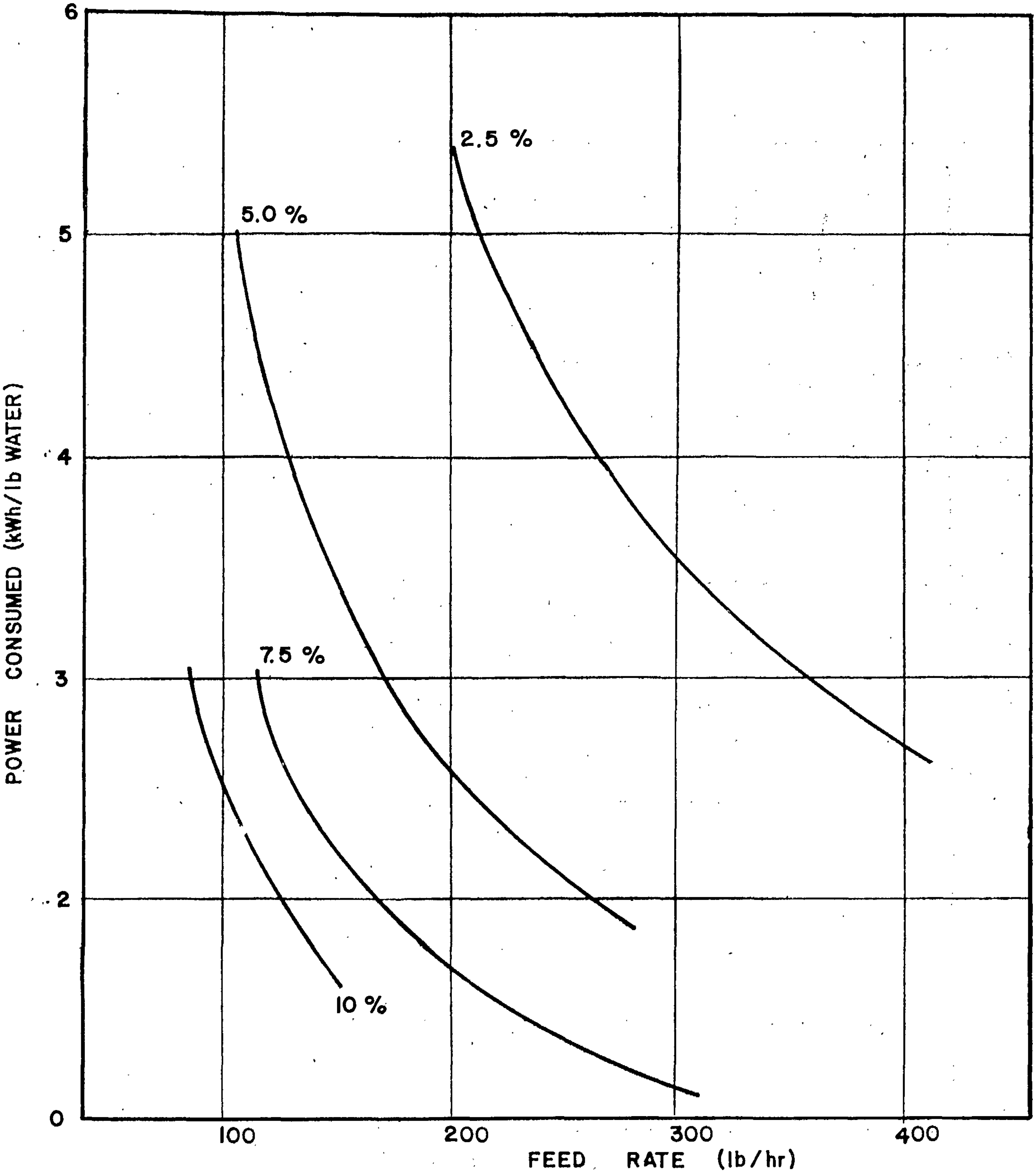

FIGURE 19. FEED RATE VS POWER CONSUMED (VARIOUS MOISTURE CONTENTS, %)

TABLE 6

Effect of Lifters

No. of Lifters	Conf.*	Moisture, %	Dry Product lb/hr (kg/hr)			
			Conveyor Speed, % of maximum			
			62	75	87	Average
1	1	2.5		225 (102)	225 (102)	225 (102)
1	1	5.0		180 (82)	194 (88)	187 (85)
1	1	7.5		112 (51)	112 (51)	112 (51)
1	1	10.0		86 (39)		86 (39)
2	2	2.5	210 (95.5)	255 (116)	269 (122)	265.5 (111)
2	2	5.0	172 (78)	180 (82)		176 (80)
2	2	7.5	158 (72)	158 (72)		158 (72)
2	2	10.0		90 (41)	82 (37)	86 (39)
3	3	2.5	359 (163)	322 (146)	330 (150)	337 (153)
3	3	5.0	210 (95.5)	195 (89)	210 (95.5)	205 (93)
3	3	7.5	150 (68)	135 (61)	135 (61)	140 (63)
3	3	10.0	105 (48)	97 (44)	135 (61)	112 (51)
4	4	2.5		410 (186)	410 (186)	410 (186)
4	4	5.0		195 (89)	254 (115)	225 (102)
4	4	7.5		172 (78)	225 (102)	198.5 (98)
4	4	10.0	105 (48)	120 (54.5)		112.5 (51)

*See Figure 11

Having established the advantage of multiple lifters a study was made of various slope configurations. The 6-in. (15-cm) heater-to-bed distance was again used with the same feed at two moisture levels. The results are summarized in Table 7.

TABLE 7

Effect of Lifter Slope

Lifter Configuration*	Moisture %	Dry Product lb/hr (kg/hr) Conveyor Speed, % of maximum			
		62	75	82	Average
4	7.5	169 (77)		139 (63)	154 (70)
5	7.5	150 (68)	142 (64.5)	135 (61.5)	142 (64.5)
6	7.5		157 (71.5)		157 (71.5)
7	7.5	157 (71.5)			157 (71.5)
7	5.0		225 (102)	254 (115)	239.5 (108.5)
8	5.0		225 (102)	240 (109)	232.5 (105.5)

*See Figure 11

The effect of drags was examined as an adjunct to lifters as shown in Table 8. Because the quartz sand did not form pellets, the feed for Table 8 trials was limestone crushed to minus 28 mesh. For all trials the 6-in. (15-cm) heater-to-bed distance was used and the moisture content was 5 per cent. Drags were located immediately after lifters as in the experiments reported in Part 1.

TABLE 8

Effect of Drags

Lifter Configuration*	No. of Drags	Dry Product lb/hr (kg/hr) Conveyor Speed, % of maximum			
		62	75	87	Average
0	0	112 (51)	75 (34)	68 (31)	85 (38.5)
1	0	120 (54.5)	108 (49)	105 (48)	111 (50.5)
1	1	127 (58)	116 (53)		121.5 (55.3)
2	1	157 (71.5)	150 (68)		153.5 (69.5)
2	2	187 (85)	180 (82)		183.5 (83.5)
3	2	199 (90.5)	180 (82)		189.5 (86)
3	3	232 (105)	218 (99)		225 (102)
4	3	247 (112)	218 (99)		232.5 (105.5)
4	4	255 (116)	243 (110)		249 (113)

*See Figure 11

The effect of heater-to-bed distance is reported in Table 9. These trials were made with No. 4 (Figure 11) lifter configuration.

TABLE 9

Effect of Heater to Bed Distance

Moisture %	Heater to Bed in. (cm)	Dry Product lb/hr (kg/hr) Conveyor Speed, % of maximum			
		62	75	87	Average
2.5	4 (10)	562 (255)	450 (204)	480 (218)	497 (225.5)
2.5	6 (15)		410 (186)	410 (186)	410 (180)
5.0	4 (10)	278 (126)		270 (122)	274 (124)
5.0	6 (15)		195 (89)	254 (115)	225 (102)
7.5	4 (10)	210 (95.5)		210 (95.5)	210 (95.5)
7.5	6 (15)		172 (78)	225 (102)	198.5 (90)
10.0	4 (10)		150 (68)	143 (65)	146.5 (66.5)
10.0	6 (15)	105 (48)	120 (54.5)		112.5 (51)

A series of trials with decreasing sizes is shown in Table 10. The feed was limestone and the lifter configuration was No. 4 (Figure 11) in all cases. Rollers were used when feed tended to pelletize. Heater-to-bed distance was 6 in. (15 cm) throughout.

TABLE 10

Effect of Feed Size

Run No.	Feed Size	Moisture %	Rollers	Amount dried lb/hr (kg/hr)
85	3/8 to 1/2 in.	2.6	-	600 (272.5)
86	3/8 in. to 4 mesh	7.5	-	300 (136)
83	-4 mesh	5.0	-	200 (91)
87	-4 mesh	7.5	2: 3-Al 3: 3-Al	150 (68)
84	10 to 20 mesh	5.0	-	273 (124)
89	-10 mesh	5.0	2: 3-Al 3: 3-Al	200 (91)
88	-10 mesh	7.5	2: 3-Al 3: 3-Al	188 (85.5)

Discussion

The remarks given for Part 1 regarding the handling of various materials apply equally to Part 2. Trials 90 to 95 in Part 2 generally reflect the application of experience gained, and technique developed for difficult drying situations. The equipment will handle any material which can be transported by vibrating conveyor, and the chief difficulties are with fine materials of marginal moisture content, i.e., moisture will not vibrate out but the material forms sticky pats which cool the conveyor bottom and have to be prodded to move from the feed end. In general, however, the equipment used for Part 2 satisfies the bulk drying requirements of the Milling Section.

It was found that the transporting capacity for drying was much less than that for dry solids (Figure 12), even at low moisture contents (compare Run 5 and Run 7, Appendix B).

As shown in Table 6 and as expected, the amount dried generally decreased as moisture content increased. The amount dried generally increased with the number of lifters used regardless of moisture content, but rather surprisingly also tended to increase with slower traverse time. No pronounced improvement was demonstrated through increasing the slopes of the lifters (Table 7).

Table 8 indicated improvement in drying capacity with increased number of lifters and with increased number of drags.

Table 9 shows that at all levels of moisture, the effect of greater heater-to-bed distance was to lower drying capacity.

Capacity is also shown to drop as feed size decreases (Table 10). However, granular material, e.g., 10 to 20 mesh, Run 84, is easier to dry than feeds containing fines, Runs 87 and 88.

Power requirements in Part 2 trials followed the trends established for Part 1. This is indicated in Table 11 where average results for 10 and 20 feet of conveyor capacity, Part 2, are compared with the same data for Part 1 (see Table 4).

TABLE 11

Comparison of Results: Part 1 and Part 2

Part No.	No. of Traverses	Conveyor length ft (m)	lb/hr water removed	kWh/lb water removed	kWh/lb solids dried
1	1	10 (3)	2.19	2.25	0.100
2	1	"	10.53	2.62	0.162
1	2	20 (6)	4.40	2.73	0.235
2	2	"	13.86	4.27	0.960

Table 11 shows that power consumed increases with conveyor length and with amount of water removed. The average power consumed in Part 2 trials is higher than for Part 1 but the average amount of water removed is much greater. It should also be noted that these are averages of all trials made regardless of performance. Perhaps a more accurate assessment may be made from Figures 5 and 16. Figure 5 indicates that a power expenditure of 2 kWh/lb water will extract 2 lb/hr of water using the equipment of Part 1, whereas Figure 16 indicates that the same power expenditure will extract 14 lb/hr of water using Part 2 equipment. Similarly, Figure 7 (Part 1) indicates that an expenditure of 0.1 kWh/lb will dry 40 lb/hr of solids, while Figure 18 (Part 2) indicates that the same power will dry 285 lb/hr of solids.

To obtain an approximation of costs, a treatment similar to that for Part 1 was applied, with the same assumption of 2.5¢ per kWh for power. This is shown in Table 12.

TABLE 12

Estimated Drying Costs, Part 2

Run No.	Size	Feed Rate lb/hr (kg/hr)	Heater Height in. (cm)	Moist. %	Power used (kWh)		Cost $/Ton
					Trial	Per Ton	
85	¾ to ½ in.	600 (272.5)	6 (15)	2.6	27.30	91	2.28
43	28 to 100 mesh	562 (258)	4 (10)	2.5	27.27	97	2.43
36	"	410 (186)	6 (15)	2.5	27.47	134	3.35
47	"	270 (122.5)	4 (10)	5.0	27.47	203	5.08
83	"	200 (91)	6 (15)	5.0	27.33	273	6.83
49	"	210 (95.5)	4 (10)	7.5	27.47	262	6.54
39	"	172 (78)	6 (15)	7.5	27.37	318	7.95
51	"	143 (65)	4 (10)	10.0	27.47	384	9.60
42	"	120 (54.5)	6 (15)	10.0	27.37	456	11.40
94-1	"	60 (27)	6 (15)	18.6	27.30	910	22.75
Totals		2747				3128	78.41
Average		275 (124)				312.8	7.84
Average, All Trials						324	8.10

The Part 1 and Part 2 test results are more closely compared in Table 13.

TABLE 13

Cost Comparison, Part 1 and Part 2
(for trials in Tables 4 and 12)

Part No.	Av Feed Rate lb/hr (kg/hr)	Av Water Removed lb/hr (kg/hr)	Av Power Used Kw/ton	Av Cost $/ton
1	67 (30.5)	2.42 (1.10)	258	6.45
2	275 (124)	13.63 (6.21)	313	7.84

Table 13 shows that capacity is the chief difference between the equipment used for Part 1 and Part 2. The Part 2 equipment will handle feed at a rate satisfactory to the needs of the Section and will dry (or remove water) much more rapidly than that for Part 1. The method has been used regularly and successfully for the bulk drying of several products as required by the Section over the past two years.

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APPENDIX "A"

EXPERIMENTAL DETAILS - PART 1

APPENDIX "A"

EXPERIMENTAL DETAILS, PART I

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
11	2 to 1 in.	SS	165 (75)	2.9	65	2	0	0	7(17.5)	0	Tends to jam. Lumps dry after discharging.
13	1 to ½ in.	LS	130 (59)	3.0	65	3	0	0	7(17.5)	0	Would take higher feed rate.
14	½ in. to 4 mesh	Gr	67 (30.4)	3.4	72	3	0	0	7(17.5)	0	Moisture pool at feed end.
15	-½ in.	Gr	44 (20.0)	4.6	84	2	0	0	7(17.5)	0	Good performance
16	-½ in.	Gr	43 (19.5)	4.6	87	2	0	0	7(17.5)	0	" "
17	½ in. to 100 mesh	Gr	25 (11.4)	7.4	75	2	0	0	7(17.5)	0	Dries while cascading at discharge.
9	-4 mesh	LS	50 (22.7)	4.6	82	2	0	0	7(17.5)	0	Good performance.
10	-4 mesh	LS	30 (13.6)	7.4	88	2	0	0	7(17.5)	0	Dry but fines coat conveyor.
47	-4 mesh	S	196 (89)	1.9	83	2	0	0	6(15.0)	0	Good drying
23	-10 mesh	LS	50 (22.7)	4.6	75	4	3	0	7(17.5)	-	Forms some pellets. Not dry.
24	-10 mesh	LS	34 (15.4)	7.4	83	4	3	0	7(17.5)	-	6-mesh screen/baffle blocks feed.
25	-10 mesh	LS	30 (13.6)	7.4	84	4	3	0	7(17.5)	-	6 mesh-screen/baffle at 35° blocks feed.
26	-10 mesh	LS	-	10.0	85	4	4	0	7(17.5)	-	Water pools at feed end.

(1) See Table 1. (2) See Figure 2. (3) See Figure 3. (4) Distance from conveyor floor to bottom of reflector.

APPENDIX "A" (CONT)

EXPERIMENTAL DETAILS, PART I

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
27	-10 mesh	LS	30 (13.6)	8.5	87	4	4	0	7(17.5)	2.0	Not dry.
28-1	-10 mesh	LS	50 (22.7)	8.5	94	4	4	0	7(17.5)	2.9	Hard to transport - sticky.
28-2	-10 mesh	LS	43 (19.5)	2.9	83	4	4	0	7(17.5)	0	Good drying.
49-1	-10 mesh	LS	86 (39.1)	8.3	100	4	0	2:3-W 4:$1\frac{1}{4}$-S	5(12.5)	4.3	
49-2	-10 mesh	LS	86 (39.1)	4.3	100	4	4	2:3-Al 4:$1\frac{1}{4}$-S	5(12.5)	0.4	
52.1	-10 mesh	LS	77 (35.0)	8.2	100	4	0	2:3-W	6(15.0)	4.0	
52-2	-10 mesh	LS	77 (35.0)	4.0	100	4	4	2:3-W 4:$1\frac{1}{4}$-S	6(15.0)	0.32	
53-1	-10 mesh	LS	75 (34.1)	8.6	100	4	0		7(17.5)	6.04	
53-2	-10 mesh	LS	75 (34.1)	6.0	100	4	4	2:3-W 4:$1\frac{1}{4}$-S	7(17.5)	0.91	
5	14 to 20 mesh	LS	33 (15.0)	4.6	83	2	0	0	7(17.5)	0	
6	14 to 20 mesh	LS	30 (13.6)	4.6	83	2	0	0	7(17.5)	0	Dry by middle of conveyor. Would take faster feed.
8	14 to 20 mesh	LS	47 (21.4)	4.6	83	2	0	0	7(17.5)	0	Well balanced operation.
50	14 to 20 mesh	LS	55 (25.0)	4.7	100	4	4	2:3-W 4:$1\frac{1}{4}$-S	5(12.5)	0.05	

APPENDIX "A" (CONT)

EXPERIMENTAL DETAILS, PART I

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
51	14 to 20 mesh	LS	72 (32.7)	4.7	100	4	4	2:3-W 4:1¼-S	6(15.0)	0.24	
54	14 to 20 mesh	LS	53 (24.1)	5.1	100	4	4	2:3-W 4:1¼-S	7(17.8)	0.18	
18	-14 mesh	S	36 (16.4)	3.8	62	3	0	0	7(17.5)	0	Some pellets formed
19	-14 mesh	S	33 (15.0)	4.5	67	3	0	0	7(17.5)	0	Some pellets.
20	-14 mesh	S	25 (11.4)	7.4	67	4	3	0	7(17.5)	0	Some pellets.
21-1	-14 mesh	S	30 (13.6)	10.0	71	4	3	0	7(17.5)	1.0	
21-2	-14 mesh	S	60 (27.2)	1.0	67	4	3	0	7(17.5)	0	Could take higher feed rate.
22-1	-14 mesh	S	60 (27.2)	10.0	75	4	3	0	7(17.5)	5.7	
22.2	-14 mesh	S	60 (27.2)	5.7	75	4	3	0	7(17.5)	1.6	
22.3	-14 mesh	S	125 (57)	1.6	75	4	3	0	7(17.5)	0	
29	-28 mesh	LS	27 (12.3)	4.6	83	4	3	0	7(17.5)	-	Pelletizes badly.
30	-28 mesh	LS	21 (9.6)	7.4	83	4	4	0	7(17.5)	-	Pelletizes badly.
31	-28 mesh	LS	21 (9.6)	7.4	83	4	5	0	7(17.5)	-	Pelletizes badly.

APPENDIX "A" (CONT)

EXPERIMENTAL DETAILS, PART I

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
32.	-28 mesh	LS	23 (10.4)	7.4	89	4	4	2:1¼-S 4:1¼-S	7(17.5)	1.0	Pellets pass under rollers without breaking.
33	-28 mesh	LS	28 (12.7)	7.4	87	4	4	2:2-S 4:2-S	7(17.5)	1.0	Pellets pass under rollers.
35-1	-28 mesh	LS	50 (22.7)	7.4	92	4	4	2:2½-S 4:3-A1	7(17.5)	2.7	Pellets broken down.
35-2	-28 mesh	LS	68 (30.9)	2.7	96	4	4	2:3-A1 4:3-A1	7(17.5)	0	Pellets eliminated
36	-28 mesh	LS		9.9	100	4	4	2:3-A1 4:3-A1	7(17.5)		Blocks. Too wet to convey.
37-1	-28 mesh	LS	50 (22.7)	8.9	100	4	4	2:3-A1 4:3-A1	7(17.5)	5.3	No blocking. No pellets.
37-2	-28 mesh	LS	40 (18.2)	5.3	100	4	4	2:3-A1	7(17.5)	0	
38-1	-28 mesh	LS	25 (11.4)	10.1	100	4	4	2:3-A1 4:3-A1	7(17.5)	2.4	Builds up behind lead roller.
38-2	-28 mesh	LS	60 (27.2)	2.4	100	4	4	2:3-A1 4:3-A1	7(17.5)	0	
39-1	-28 mesh	LS	31 (14.1)	9.8	100	4	4	2:3-T 4:3-A1	7(17.5)	4.8	Sticks behind lead roller.
39-2	-28 mesh	LS	28 (12.7)	4.8	100	4	4	2:3-T 4:3-A1	7(17.5)	0.2	
40-1	-28 mesh	LS	24 (10.9)	9.9	100	4	4	2:3-W 4:3¼-A1	7(17.5)	2.0	
40-2	-28 mesh	LS	43 (19.5)	2.0	100	4	4	2:3-W 4:3¼-A1	7(17.5)	0.2	

APPENDIX "A" (CONT)

EXPERIMENTAL DETAILS, PART I

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
41-1	-28 mesh	LS	33 (15.0)	9.6	100	4	4	2:4½-W 4:3¼-Al	7(17.5)	2.6	
41-2	-28 mesh	LS	28 (12.7)	2.6	100	4	4	2:4½-W 4:3¼-Al	7(17.5)	0.1	
42-1	-65 mesh	LS	14.5 (6.6)	13.8	100	4	4	0	7(17.5)	12.4	Lumpy and sticky.
42-2	-65 mesh	LS	17.6 (8.0)	12.4	100	4	4	2:4-W 4:3¼-Al	7(17.5)	0.2	No lumps or pellets
43-1	-65 mesh	LS	29 (13.2)	13.0	100	4	4	0	7(17.5)	9.9	Stickiness relieved by preheating conveyor.
43-2	-65 mesh	LS	17.2 (7.8)	9.9	100	4	4	2:4-W 4:1¼-S	7(17.5)	0.7	Slow but no stoppage.
44-1	-65 mesh	LS	46.5 (21.0)	11.8	100	4	0	0	7(17.5)	8.9	Passes preheated conveyor satisfactorily.
44.2	-65 mesh	LS	46.5 (21.0)	8.9	100	4	2	2:3-W 4:1¼-S	7(17.5)	2.4	
44-3	-65 mesh	LS	35.2 (16.0)	2.4	100	4	4	2:3-Al 4:1¼-S	7(17.5)	0.1	Could have taken faster feed.
45-1	-65 mesh	LS	47 (21.4)	14.1	100	4	0	0	7(17.5)	10.7	
45-2	-65 mesh	LS	47 (21.4)	10.7	100	4	2	2:3-W 4:1¼-S	7(17.5)	6.3	
45-3	-65 mesh	LS	47 (21.4)	6.3	100	4	4	2:3-W 4:1¼-S	7(17.5)	0.35	

APPENDIX "A" (CONT)

EXPERIMENTAL DETAILS, PART I

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
46-1	-65 mesh	LS	52 (23.6)	11.7	100	4	0	0	6(15.0)	8.9	
46-2	-65 mesh	LS	52 (23.6)	8.9	100	4	2	2:3-W 4:$1\frac{1}{4}$-S	6(15.0)	2.9	
46-3	-65 mesh	LS	52 (23.6)	2.9	100	4	4	2:3-W 4:$1\frac{1}{4}$-S	6(15.0)	0.04	
48-1	-65 mesh	LS	42 (19.1)	10.8	100	4	4	0	5(12.5)	8.2	
48-2	-65 mesh	LS	71 (32.2)	8.2	100	4	2	2:3-W 4:$1\frac{1}{4}$-S	5(12.5)	4.5	
48-3	-65 mesh	LS	71 (32.2)	4.5	100	4	4	2:3-W 4:$1\frac{1}{4}$-S	5(12.5)	0.1	

APPENDIX "B"

EXPERIMENTAL DETAILS - PART 2

APPENDIX "B"

EXPERIMENTAL DETAIL, PART 2

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
1	14 to 28 mesh	S	5610 (2550)	0	100	–	–	–	–	–	Capacity trial
2	"	"	1550 (706)	0	75	–	–	–	–	–	" "
3	"	"	220 (100)	0	50	–	–	–	–	–	" "
44	40 to 100 mesh	S	2710 (1230)	0	100	–	–	–	–	–	" "
5	"	"	780 (354)	0	75	–	–	–	–	–	" "
6	"	"	100 (45.4)	0	50	–	–	–	–	–	" "
7	28 to 100 mesh	S	225 (102)	2.5	75	1	0	0	6(15.0)	0	
8	"	"	225 (102)	2.5	87	1	0	0	"	0	
9	"	"	180 (82)	5.0	75	1	0	0	"	0	
10	"	"	194 (88)	5.0	87	1	0	0	"	0	
11	"	"	112 (51)	7.5	75	1	0	0	"	0	
12	"	"	112 (51)	7.5	87	1	0	0	"	0	
13	"	"	86 (39)	10.0	75	1	0	0	"	0	

(1) See Table 1 (2) See Figure 11 (3) See Figure 3. (4) Distance from top of bed to face of "solar" panel.

APPENDIX "B" (CONT)
EXPERIMENTAL DETAIL, PART 2

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
14	28 to 100 mesh	S	210 (95.5)	2.5	62	2	0	0	6 (15.0)	0	
15	"	"	255 (116)	2.5	75	2	0	0	"	0	
16	"	"	269 (122)	2.5	87	2	0	0	"	0	
17	"	"	172 (78)	5.0	62	2	0	0	"	0	
18	"	"	180 (82)	5.0	75	2	0	0	"	0	
19	"	"	158 (72)	7.5	62	2	0	0	"	0	
20	"	"	158 (72)	7.5	75	2	0	0	"	0	
21	"	"	90 (41)	10.0	75	2	0	0	"	0	
22	"	"	82 (37)	10.0	87	2	0	0	"	0	
23	"	"	359 (163)	2.5	62	3	0	0	"	0	
24	"	"	322 (146)	2.5	75	3	0	0	"	0	
25	"	"	330 (150)	2.5	87	3	0	0	"	0	

APPENDIX "B" (CONT)
EXPERIMENTAL DETAIL, PART 2

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
26	28 to 100 mesh	S	210 (95.5)	5.0	62	3	0	0	6(15.0)	0	
27	"	"	195 (89)	5.0	75	3	0	0	"	0	
28	"	"	210 (95.5)	5.0	87	3	0	0	"	0	
29	"	"	150 (68)	7.5	62	3	0	0	"	0	
30	"	"	135 (61)	7.5	75	3	0	0	"	0	
31	"	"	135 (61)	7.5	87	3	0	0	"	0	
32	"	"	105 (48)	10.0	62	3	0	0	"	0	
33	"	"	97 (44)	10.0	75	3	0	0	"	0	
34	"	"	135 (61.5)	10.0	87	3	0	0	"	0	
35	"	"	410 (186)	2.5	75	4	0	0	"	0	
36	"	"	410 (186)	2.5	87	4	0	0	"	0	
37	"	"	195 (89)	5.0	75	4	0	0	"	0	
38	"	"	254 (115)	5.0	87	4	0	0	"	0	

APPENDIX "B" (CONT)
EXPERIMENTAL DETAIL, PART 2

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (Kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
39	28 to 100 mesh		172 (78)	7.5	75	4	0	0	6(15.0)	0	
40	"	"	225 (102)	7.5	87	4	0	0	"	0	
41	"	"	105 (48)	10.0	62	4	0	0	"	0	
42	"	"	120 (54.5)	10.0	75	4	0	0	"	0	
43	"	"	562 (255)	2.5	62	4	0	0	4(10.0)	0	
44	"	"	450 (204)	2.5	75	4	0	0	"	0	
45	"	"	480 (218)	2.5	87	4	0	0	"	0	
46	"	"	278 (126)	5.0	62	4	0	0	"	0	
47	"	"	270 (122.5)	5.0	87	4	0	0	"	0	
48	"	"	210 (95.5)	7.5	62	4	0	0	"	0	
49	"	"	210 (95.5)	7.5	87	4	0	0	"	0	
50	"	"	150 (68)	10.0	75	4	0	0	"	0	
51	"	"	143 (65)	10.0	87	4	0	0	"	0	

APPENDIX "B" (CONT)

EXPERIMENTAL DETAIL, PART 2

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (Kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
52	28 to 100 mesh	S	225 (102)	5.0	75	7	0	0	6(15.0)	0	
53	"	"	254 (115)	5.0	87	7	0	0	"	0	
54	"	"	225 (102)	5.0	75	8	0	0	"	0	
55	"	"	240 (109)	5.0	87	8	0	0	"	0	
56	"	"	169 (77)	7.5	62	4	0	0	"	0	
57	"	"	139 (63)	7.5	87	4	0	0	"	0	
58	"	"	150 (68)	7.5	62	5	0	0	"	0	
59	"	"	142 (64.5)	7.5	75	5	0	0	"	0	
60	"	"	135 (61.5)	7.5	87	5	0	0	"	0	
61	"	"	157 (71.5)	7.5	75	6	0	0	"	0	
62	"	"	157 (71.5)	7.5	62	7	0	0	"	0	
63	-28mesh	LS	112 (51)	5.0	62	0	0	0	"	0	
64	"	"	75 (34)	5.0	75	0	0	0	"	0	

APPENDIX "B" (CONT)
EXPERIMENTAL DETAIL, PART 2

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
65	-28 mesh	LS	68 (31)	5.0	87	0	0	0	6(15.0)	0	
66	"	"	120 (54.5)	5.0	62	1	0	0	"	0	
67	"	"	108 (49)	5.0	75	1	0	0	"	0	
68	"	"	105 (48)	5.0	87	1	0	0	"	0	
69	"	"	127 (58)	5.0	62	1	1	0	"	0	
70	"	"	116 (53)	5.0	75	1	1	0	"	0	
71	"	"	157 (71.5)	5.0	62	2	1	0	"	0	
72	"	"	150 (69)	5.0	75	2	1	0	"	0	
73	"	"	187 (85)	5.0	62	2	2	0	"	0	
74	"	"	180 (82)	5.0	75	2	2	0	"	0	
75	"	"	199 (90.5)	5.0	62	3	2	0	"	0	
76	"	"	180 (82)	5.0	75	3	2	0	"	0	
77	"	"	232 (105)	5.0	62	3	3	0	"	0	

APPENDIX "B" (CONT)

EXPERIMENTAL DETAIL, PART 2

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
78	-28 mesh	LS	218 (99)	5.0	75	3	3	0	6(15.0)	0	
79	"	"	247 (112)	5.0	62	4	3	0	"	0	
80	"	"	218 (99)	5.0	75	4	3	0	"	0	
81	"	"	255 (116)	5.0	62	4	4	0	"	0	
82	"	"	243 (110)	5.0	75	4	4	0	"	0	
83	-4 mesh	"	200 (91)	5.0	65	4	0	0	"	0	
84	10 to 20 mesh	"	273 (124)	5.0	70	4	0	0	"	0	
85	3/4 to 1/2 in.	"	600 (272.5)	2.6	75	4	0	0	"	0	
86	3/8 in. to 4 mesh	"	300 (136)	7.5	65	4	0	0	"	0	
87	-4 mesh	"	150 (68)	7.5	70	4	0	2:3-A1 3:3-A1	"	0	
88	-10 mesh	"	188 (85.5)	7.5	60	4	0	2:3-A1 3:3-A1	"	0	
89	-10 mesh	"	200 (91)	5.0	65	4	0	2:3-A1 3:3-A1	"	0	
90	-100 mesh	S	100 (45.5)	14.3	60	4	0	2:3-A1 3:3-A1	"	0	

APPENDIX "B" (CONT)
EXPERIMENTAL DETAIL, PART 2

RUN NO.	FEED				CONVEYOR				HEATER HEIGHT in. (cm.)	MOISTURE IN PRODUCT %	NOTES
	SIZE	TYPE (1)	RATE lb/hr (kg/hr)	MOISTURE %	SPEED % of max.	LIFTER CONF(2)	DRAGS No.	ROLLERS (3)			
91-1	63% -325 mesh	S-C	24 (10.9)	13.7	60	4	0	-	6(15.0)	10.9	Gummy, slow feeding, sticks to conveyor.
91-2	"	"	55 (25)	10.9	60	4	0	2:3-A1 3:3-A1	"	0.2	Good drying. Lumps break readily under rollers.
92-1	-100mesh	LS	75 (34)	14.3	80	4	0	-	"	3.5	Gummy, as 91-1.
92-2	"	"	63 (28.5)	3.5	60	4	0	2:3-A1 2:3-A1	"	0.1	Good drying, as 91-2.
93-1	-48 mesh	B	100 (45.5)	9.7	70	4	0	-	"	1.6	Lumpy product.
93-2	"	"	200 (91)	1.6	100	4	0	2:3-A1 3:3-A1	"	0.1	Good drying.
94-1	-35 mesh	P	60 (27)	18.6	65	4	0	-	"	5.0	Gummy, etc.
94-2	"	"	60 (27)	5.0	60	4	0	2:3-A1 3:3-A1	"	0.6	Fair drying. Lumps break well.
95-1	very fine	M	54 (24.5)	37.1	70	4	0	-	"	22.1	Gummy, hard to move over conveyor. Lumpy product.
95-2	"	"	36 (16.3)	22.1	50	4	0	2:3-A1 3:3-A1	"	0.43	Lumps break well. Organic matter ignites.