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MATERIAL-TRANSPORTING CHARACTERISTICS OF SELECTED VIBRATING EQUIPMENT

R. A. WYMAN

MINERAL PROCESSING DIVISION

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MATERIAL-TRANSPORTING CHARACTERISTICS OF SELECTED VIBRATING EQUIPMENT

by

R. A. Wyman*

ABSTRACT

In order to provide for the performance of completely integrated pilot-plant operations, and to facilitate bulk-materials-handling in the Industrial Minerals Milling Section of the Mineral Processing Division, a study was made of transporting and feeding machines that would provide the necessary characteristics of versatility, mobility, accuracy, and ease of cleaning. Vibrating equipment came closest to filling all of these requirements, and the Section acquired a conveyor unit, a short elevator and two types of feeder, to allow for study of material movement by this means.

Experimental work indicated that the machines selected had a broad range of application to the movement of bulk minerals and rocks; would be appropriate for connecting links between processing units; and were reliable, easy to maintain, and easy to clean. Capacities and operating characteristics are outlined.

Within the confines of an experimental processing plant, requiring changes for each investigation undertaken, the mobility of such units make them very useful tools. They present a neat appearance and are readily stored when not in service. Although presenting drawbacks in some areas of performance, the over-all practicality of these units for the purposes required was clearly demonstrated.

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Direction des mines

CARACTÉRISTIQUES DE CERTAINES INSTALLATIONS DE TRANSPORT PAR VIBRATION

par

R. A. Wyman*

RÉSUMÉ

En prévision de la mise en oeuvre d'opérations industrielles complètement intégrées, et pour accélérer la manutention des matériaux en vrac dans la Section de broyage des minéraux industriels de la Division du traitement des minéraux, on a entrepris une étude portant sur les machines de transport et d'alimentation dotées des caractéristiques suivantes: souplesse, mobilité, précision et facilité de nettoyage. Les appareils vibratoires de transport ont donné les meilleurs résultats et la Section a acheté un convoyeur, un élévateur court et deux dispositifs d'alimentation qui ont servi à l'étude du transport des matériaux par ce moyen.

Les expériences ont démontré que les machines choisies avaient de nombreuses applications pour le transport en vrac des minéraux et des roches; on pourrait aussi les utiliser pour relier entre eux les différents ateliers de traitement d'une usine. Ces machines sont sûres, faciles à entretenir et à nettoyer. On trouvera dans cette étude des chiffres sur la capacité et les caractéristiques de fonctionnement.

La mobilité de ces machines les rend particulièrement utiles dans une usine de traitement expérimentale, où les conditions d'utilisation changent avec chaque expérience. D'apparence agréable, on peut les ranger facilement lorsqu'on n'en a pas besoin. Ces machines, bien que présentant quelques inconvénients à certains égards, ont quand même démontré sans conteste leur utilité pour les fins recherchées.

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INTRODUCTION

For many years, the material-handling facilities in the industrial minerals mill of the Mineral Processing Division at the Mines Branch have not afforded a continuous flow. Tonnage lots have had to be moved through various stages of pilot-plant processing by means of containers. At first this was done by hand, in wash tubs holding 150 to 200 pounds of material. Later, skips were introduced for moving half-ton quantities. These could be handled by a small hydraulic lift truck and a one-ton-capacity electric hoist. Although satisfactory for some stages of operation, the skips proved too limited in scope and were somewhat cumbersome to handle. Eventually, equipment for the moving, raising and dumping of 45-gallon drums was obtained, allowing one man to manipulate approximately 500 pounds of material. The drums also provide temporary storage.

Although the drum system would accommodate single-stage operations, it could not accommodate a continuous, interlocked, pilot-mill operation. Long-range planning for more extensive processing facilities stimulated a search for a more versatile means of continuously transporting materials. At the same time, the need for more accurate feeding of all types and sizes of rock came under consideration.

The wide variety of processing requirements for industrial minerals calls for "all-purpose" performance by both transport and feeding equipment. To provide the necessary versatility, units would have to be mobile, accurate, easy to clean, and able to handle many types and sizes of material either damp or dry. Vibrating equipment gave the greatest promise of filling these requirements.

For feeding, two types of equipment were selected, a parts feeder which could deliver up to 4-inch lump, and a vibrating screw feeder which could handle material below about 4 mesh in particle size; for horizontal movement, 10-foot sections of vibrating conveyor, and for elevation, 6- or 8-foot-lift vibrating elevators. By means of a number of conveyor sections and elevators, material could be moved from one process step to another, discharged into the correct feeder, and fed at the necessary rate.

A single unit of each of the four types of machine was acquired, as illustrated in Figures 1 to 4, and experiments were carried out to indicate the approximate work range of each.

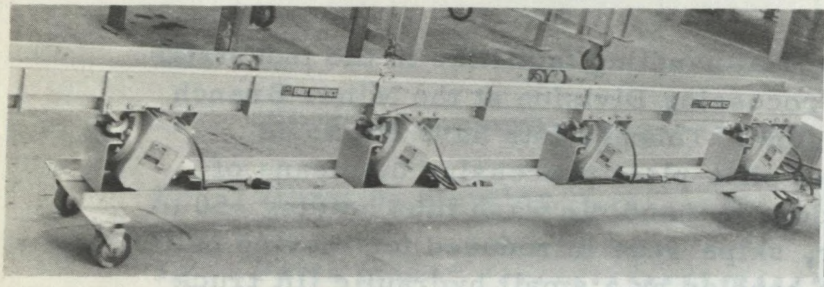

Figure 1

Vibrating conveyor.

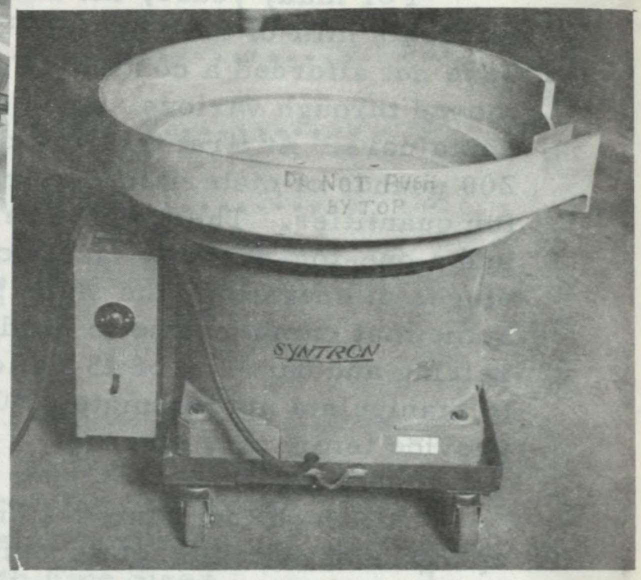

Figure 3

Parts feeder.

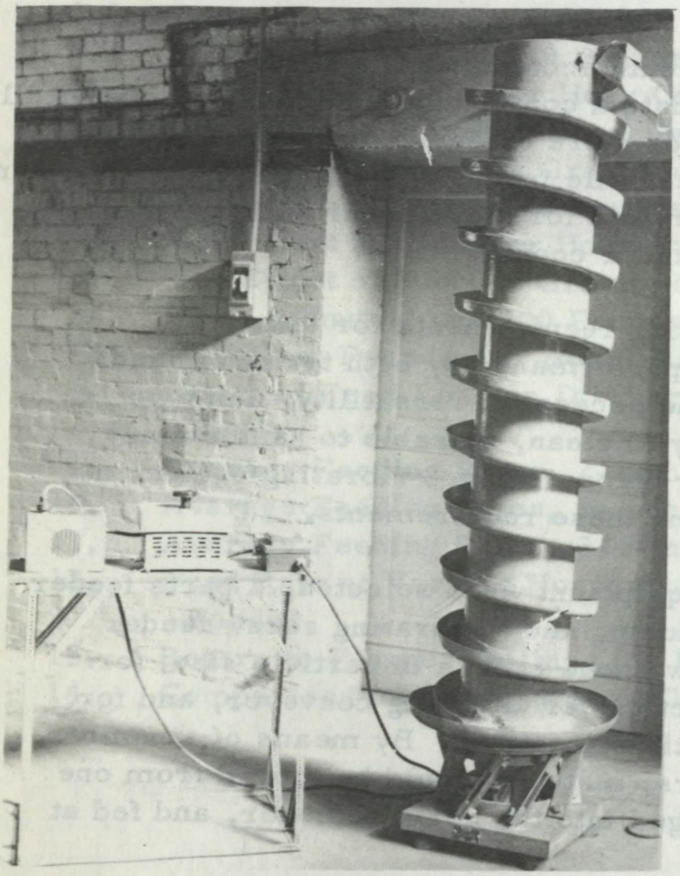

Figure 2

Vibrating elevator.

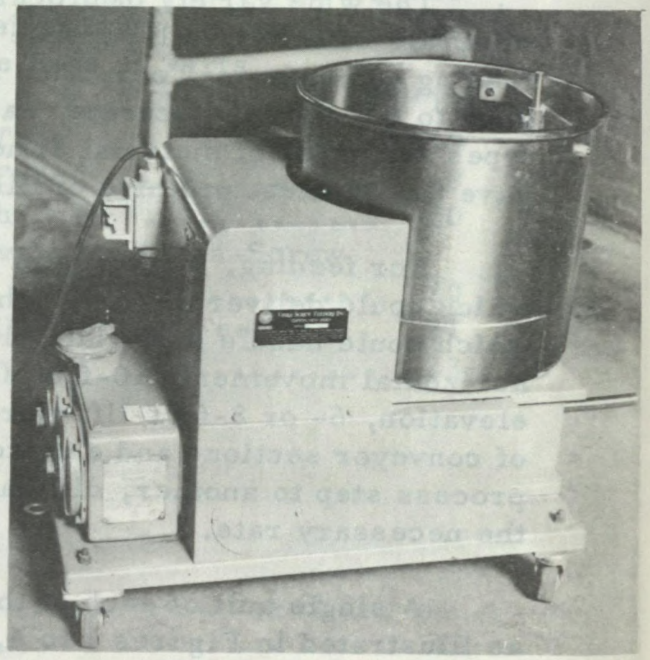

Figure 4

Vibra-Screw feeder.

MOVEMENT OF MATERIAL BY VIBRATION

Material to be conveyed is placed on a smooth surface supported by inclined springs. The springs are drawn back a short distance then allowed to snap forward, tossing the load ahead. Although this action may be produced in a number of ways, one of the most common is by electromagnet. Vibrations produced by this means are comparatively rapid, and the spring movement short, so that the load appears to travel continuously ahead. The frequency of vibration may be varied by a voltage regulator.

MATERIALS USED

Materials were selected to give a wide range of size and spread in specific gravity, in order to outline the capabilities of the machines for practical purposes. Table 1 lists these materials. Samples already on hand were employed.

TABLE 1

Material Used in Experiments

Material	Size	Specific Gravity
Magnesite	6 inch	3.1
Sandstone	4 inch	2.6
Sandstone	2 1/2 to 2 inch	2.6
Sandstone	2 to 1 1/2 inch	2.6
Barite-Fluorite	-2 inch	3.7
Sandstone	1 1/2 to 1 inch	2.6
Sandstone	1 to 3/4 inch	2.6
Fluorite	3/4 in. to 4 mesh	3.1
Barite	3/4 in. to 4 mesh	4.4
Limestone	4 to 20 mesh	2.7
Limestone	-4 mesh	2.7
Barite	-4 mesh	4.4
Limestone	-10 mesh	2.7
Syenite	-10 mesh	2.6
Barite	-10 mesh	4.4
Limestone	10 to 28 mesh	2.7
Limestone	14 to 20 mesh	2.7
Limestone	-28 mesh	2.7
Silica sand	-28 mesh	2.6
Nepheline Syenite	-28 mesh	2.6
Barite	-48 mesh	4.4

TRANSPORTING EQUIPMENT

Vibrating Conveyor

1) Description: The unit consists of 10 feet of tray 6 inches wide, with 3-inch sides made of mild steel. This is vibrated by 4 drives equally spaced along its length, mounted on a base of angle iron. The whole is made mobile with rubber-tired casters. The vibrating frequency is varied by means of a voltage regulator fed with 110-volt, single-phase, 60-cycle alternating current. The regulator is mounted at the feed end below tray level. Power may be picked up by plugging into any 110-volt outlet.

2) Action: The action tosses the load ahead in a series of very small steps which give the impression of a smooth, continuous flow.

3) Experiments and Results: Experiments were made on dry material from 6-inch lump to minus 48 mesh with the conveyor horizontal and at low, medium and high (maximum) vibrating frequencies. The effect of sloping the conveyor at 3.5 and 7.0 degrees was observed for a number of material sizes. Experiments to ascertain the effect of moisture in the feed were made on a number of samples containing fines (powdered material). These are the samples designated in Table 1 by a minus (-) sign.

A general method of conducting the experiments to provide maximum information was sought. Eventually it was decided to record the time required for the complete passage of 100 pounds of sample over the conveyor from point of entry to point of discharge. Although this would not provide maximum capacity figures, it would allow observation of behaviour for filling, loaded and discharge conditions. It would provide comparative figures indicative of carrying capacity, and samples of discharge taken during the loaded period would give a check on loaded capacity.

A record of the experiments with the vibrating conveyor is given in Appendix 1. Table 2A shows the passage time in minutes for 100 pounds of material at various settings, and Table 2B gives the equivalent pounds-per-hour transporting rate.

It will be noted from these tables that material containing fines (below broken line) does not move as well as the coarser material (above broken line), except for the minus-4-mesh at maximum speed. The highest conveying rate was obtained for medium-size-range material

TABLE 2A

Time (Minutes) per 100 Pounds Crossing Conveyor

		Dry					Damp					
Slope (degrees)		0			3.5	7.0		0			3.5	7.0
Regulator Setting		50	85	120	120	120		65	85	120	120	120
Size	Sp gr						% Water					
6 in.	3.1	10.9	3.7	2.3	2.7	3.1						
2 1/2 to 2 in.	2.6	23.7	6.7	3.9								
2 to 1 1/2 in.	2.6	27.4	6.9	4.6	4.4	4.8						
1 1/2 to 1 in.	2.6	34.4	6.8	4.0								
1 to 3/4 in.	2.6	38.2	6.4	3.1								
3/4 in. to 4 m	3.1	37.5	5.2	2.3	2.8	3.2						
3/4 in. to 4 m	4.4	16.2	2.8	1.4	1.9	2.0						
4 to 20 m	2.7	42.6	4.5	1.7								
- 4 m	2.7	50.0	9.2	4.6	5.5	4.8	2.8	30.0	5.5	4.2	2.2	2.5
- 4 m	4.4	46.3	7.8	3.5	3.6	4.0						
- 10 m	2.7	62.7	18.3	6.0	7.3	6.3	4.0	30.0	8.3	2.5	2.8	3.5
- 10 m	4.4	124.0	13.5	5.7	8.8	7.1						
- 28 m	2.7		60.0	17.6	31.6	48.0	4.8	18.5	7.5	2.8	3.3	3.5
- 28 m	2.7						7.0			3.0		
- 48 m	4.4	194.0	31.8	18.3	20.0	20.7						

TABLE 2B

Equivalent Pounds Per Hour Crossing Conveyor

		Dry					Damp					
Slope (degrees)		0			3.5	7.0		0			3.5	7.0
Regulator Setting		50	85	120	120	120		65	85	120	120	120
Size	Sp gr						% Water					
6 in.	3.1	550	1635	2565	2250	1916						
2 1/2 to 2 in.	2.6	254	900	1557								
2 to 1 1/2 in.	2.6	219	865	1314	1380	1260						
1 1/2 to 1 in.	2.6	175	887	1500								
1 to 3/4 in.	2.6	157	945	1955								
3/4 in. to 4 m	3.1	160	1160	2573	2120	1890						
3/4 in. to 4 m	4.4	370	2155	4275	3167	3030						
4 to 20 m	2.7	140	1340	3474								
-4m	2.7	120	653	1310	1090	1242	2.8	200	1097	1438	2765	2400
-4m	4.4	130	766	1722	1644	1510						
-10m	2.7	96	328	1000	820	948	4.0	200	720	2400	2120	1730
-10m	4.4	48	444	1054	678	849						
-28m	2.7		100	340	189	125	4.8	324	804	2120	1800	1730
-28m	2.7						7.0			2000		
-48m	4.4	31	188	327	300	290						

(3/4 in. to 4 mesh, and 4 to 20 mesh). Carrying capacity was generally somewhat lower above this size range, and also dropped off rapidly with increasingly finer sizes. The drop-off is illustrated by isolating some of the results as has been done in Table 3.

TABLE 3

Decrease in Conveyor Capacity with Fine Sizes
(Dry feed at 4.4 sp gr)
(Top figures are time (in minutes) per 100 pounds.
Bracketed figures are pounds per hour).

Slope (degrees)	0			3.5	7.0
Regulator Setting	50	85	120	120	120
3/4 in. to 4 m	16.2 (370)	2.8 (2155)	1.4 (4275)	1.9 (3167)	2.0 (3030)
-4 mesh	46.3 (130)	7.8 (766)	3.5 (1722)	3.6 (1644)	4.0 (1510)
-10 mesh	124.0 (48)	13.5 (444)	5.7 (1054)	8.8 (678)	7.1 (849)
-48 mesh	194.0 (31)	31.8 (188)	18.3 (327)	20.0 (300)	20.7 (290)

The specific gravity of material being conveyed alters capacity. Materials of comparable fragment or particle size probably move along the conveyor at approximately equal rates for any speed setting, but heavier materials produce correspondingly higher delivered weight. This is illustrated in Table 4, in which comparison is made of different dry materials of approximately the same size in relation to the bulk density of each material. Results for minus 10 mesh proved to be erratic (see also Appendix 1).

TABLE 4

The Effect of Specific Gravity on Conveyor Capacity

(Top Figures are time (in minutes) per 100 pounds
Bracketed figures are pounds per hour.)

Slope (degrees)		0			3.5	7.0
Regulator Setting		50	85	120	120	120
Size	Bulk Density (lb/cu ft)					
3/4 in. to 4 m	82.0	37.5 (160)	5.2 (1160)	2.3 (2573)	2.8 (2120)	3.2 (1890)
3/4 in. to 4 m	102.0	16.2 (370)	2.8 (2155)	1.4 (4275)	1.9 (3167)	2.0 (3030)
-4 mesh	89.6	50.0 (120)	9.2 (653)	4.6 (1310)	5.5 (1090)	4.8 (1242)
-4 mesh	132.4	46.3 (130)	7.8 (766)	3.5 (1722)	3.6 (1644)	4.0 (1510)
-10 mesh	96.0	62.7 (96)	18.3 (328)	6.0 (1000)	7.3 (820)	6.3 (984)
-10 mesh	147.0	124.0 (48)	13.5 (444)	5.7 (1054)	8.8 (678)	7.1 (849)
-28 mesh	90.3		60.0 (100)	17.6 (340)	31.6 (189)	48.0 (125)
-48 mesh	108.4	194.0 (31)	31.8 (188)	18.3 (327)	20.0 (300)	20.7 (290)

Although fine powder reduces the carrying capacity of the conveyor if the feed is dry, a little moisture brings about a marked change. The speed of movement is greatly increased, especially in the finest materials. Small amounts of moisture tend to cause agglomeration of fine powder, thus increasing the effective particle size. It was found that at least 7.0% moisture could be tolerated in minus-28-mesh limestone at fast conveyor speed. At lower speeds with this moisture content, or with higher moisture content, the free moisture separates out under the influence of the vibrations and wets the conveyor deck, effectively checking the process. With some fine material at certain moisture contents, blobs similar to mud or putty form and stick to the conveying surface. With granular feeds, dampness causes no marked change in rate, but if free moisture can be shaken from the pieces, the carrying capacity is reduced although not stopped.

The effect of increasing slope was generally some decrease in carrying capacity for both damp and dry feeds, although the results were not altogether consistent. It was shown that the conveyor will transport well up slopes of up to 7 degrees.

Samples taken during the loaded period of operation indicated that on limestone (sp gr 2.7) the average weight being carried, in pounds per hour, was 1.29 times that shown in Table 2B. On barite (sp gr 4.4), the average weight being carried during the loaded period was 1.82 times that shown in Table 2B.

Vibrating Elevator

1) Description: A U-shaped steel trough 3 inches wide and 2 inches deep forms a spiral around a central pipe 12 inches in diameter and 6 feet high. The spiral has nine flights, or turns, to give a slope of 10 degrees. At the lower end, the trough becomes horizontal and widens to 6 inches to allow easier feeding. This entire superstructure is supported on a circle of eight inclined leaf springs and caused to vibrate by a powerful electromagnetic system. The whole assemblage is mounted on a solid steel block, 18 by 18 by 2 inches in size, which has four pliable rubber legs to prevent transfer of energy to the floor. The unit is easily moved on a small, wheeled dolly.

Control is achieved by varying direct current received via a rectifier from any 110-volt a.c. outlet. The control panel is mounted independently of the elevator and is moved separately.

2) Action: The action is essentially the same as that for the conveyor, to toss the load ahead in a series of very small steps.

3) Experiments and Results: Experiments were made on dry material from 2 1/2 in. to minus 48 mesh at low, medium and high (maximum) vibrating speeds. The effect of moisture in the feed was checked in several sizes.

The method of conducting experiments was similar to that employed with the conveyor, i.e., recording the time for complete passage of 100 pounds of feed from point of entry to point of discharge.

A record of the experiments with the vibrating elevator is given in Appendix 2. Table 5A shows the passage time in minutes for 100 pounds of sample at various settings, and Table 5B gives the equivalent pounds-per-hour passage rate. As was the case with the conveyor, a sharp drop-off in capacity occurred for material containing fine powder (below broken line). The highest conveying rate again appeared in the medium size range, 3/4 in. to 4 mesh.

A further area of comparison with the conveyor is the effect of specific specific gravity. From a comparison of Table 6 and Table 4, it can be seen that the results match closely in order although not in magnitude. In a comparison of results for the two machines it should be borne in mind that a cross-section of the conveyor trough measures 6 by 3 inches while that of the elevator trough measures 3 by 2 inches, and that the elevator has a 10-degree slope.

TABLE 5A

Time (Minutes) per 100 Pounds Passing Elevator

Regulator Setting		Dry							Damp			
		9	10	11	13	14	15	17		11.5	14	17
Size	Sp gr								% Water			
2 1/2 to 2 in.	2.6			Blocks	Blocks							
2 to 1 1/2 in.	2.6		21.4		11.9			10.7				
-2 in.	3.7				21.0		14.0	11.3	3.0	Stalls	Stalls	Stalls
1 1/2 to 1 in.	2.6	27.4			12.7			8.7				
1 to 3/4 in.	2.6	93.5			15.8			13.1				
3/4 in. to 4 m	3.1				17.6			6.5				
3/4 in. to 4 m	4.4			15.4		8.2		6.8				
14 to 20 m	2.7	61.5			20.5			14.5				
-4 m	2.7			132.5		112.5		97.3				
-4 m	4.4			37.7		28.6		24.9				
-10 m	2.7			227.3		177.3		130.0	4.0	14.5	9.0	6.3
-10 m	4.4			529.2		202.5		127.8				
-28 m	2.7					800.0		620.0	4.8	23.0	11.0	7.2
-28 m	2.7								7.0	Stalls	Stalls	
-28 m	2.6							21.0				
-48 m	4.4			910.0		409.2		320.0				

TABLE 5B

Equivalent Pounds Per Hour Passing Elevator

		Dry							Damp			
Regulator Setting		9	10	11	13	14	15	17		11.5	14	17
Size	Sp gr								% Water			
2 1/2 to 2 in.	2.6			Blocks								
2 to 1 1/2 in.	2.6		280		504			560				
-2 in.	3.7				286		428	532	3.0		Stalls	
1 1/2 to 1 in.	2.6	219			470			692				
1 to 3/4 in.	2.6	64			380			456				
3/4 in. to 4 m	3.1				340			925				
3/4 in. to 4 m	4.4			390		728		890				
14 to 20 m	2.7	97			292			413				
-4 m	2.7			45		53		62				
-4 m	4.4			159		210		240				
-10 m	2.7			26		34		46	4.0	414	666	923
-10 m	4.4			11		30		47				
-28 m	2.7					7.5		9.6	4.8	261	545	837
-28 m	2.7								7.0	Stalls		
-28 m	2.6							300				
-48 m	4.4			6.6		12.2		18.7				

TABLE 6

The Effect of Specific Gravity on Elevator Capacity
(Top figures are time (in minutes) per 100 pounds. Bracketed figures are pounds per hour.)

Slope (degrees)		10			
Regulator setting		11	13	14	17
Size	Bulk Density (lb/cu ft)				
3/4 in. to 4 m	82.0		17.6 (340)		6.5 (925)
3/4 in. to 4 m	102.0	15.4 (390)	8.2 (728)		6.8 (890)
-4 mesh	89.6	132.5 (45)		112.5 (53)	97.3 (62)
-4 mesh	132.4	37.7 (159)		28.6 (210)	24.9 (240)
-10 mesh	96.0	227.3 (26)		177.3 (34)	130.0 (46)
-10 mesh	147.0	529.2 (11)		202.5 (30)	127.8 (47)
-28 mesh	90.3			800.0 (7.5)	620.0 (9.6)
-48 mesh	108.4	910.0 (6.6)		409.2 (12.2)	320.0 (18.7)

The effect of moisture was found to be similar to that in the conveyor experiments. Sufficient moisture to cause agglomeration produced a large increase in carrying capacity, although surplus water stalled the movement of the material.

Samples taken during the loaded period of operation indicated that an average of 1.49 times the weights shown in Table 5B were actually being carried by the elevator.

FEEDING EQUIPMENT

Parts Feeder

1) Description: The three-inch parts feeder is in many respects similar to the elevator. A bowl of cast aluminum, approximately 25 inches across the bottom, is bolted to a plate supported by a circle of inclined leaf springs and caused to vibrate by a strong electromagnetic system. A solid-steel base block serves as the foundation. The machine is mounted on rubber-tired casters for mobility. The bowl expands upward from the bottom as a 1 1/2 turn spiral ledge so that it is 36 inches in diameter at the discharge point. The ledge is 3 inches wide and slightly inclined downward toward the periphery of the bowl.

Control is achieved by varying the amplitude of direct current received via a rectifier from any 110-volt, 60-cycle, a-c outlet. The frequency is 3600 vibrations per minute. Rectifier and regulator are attached to the housing below the overhang of the bowl.

2) Action: The action is similar to that of the conveyor and elevator, to toss the load ahead in a series of small steps.

3) Experiments and Results: Experiments were made on feeds ranging from 6 inches to 4 mesh, at a variety of rates ranging from approximately minimum to maximum. In addition, experiments were conducted to assess the effect of weight of feed in the bowl on the rate of discharge from the discharge point.

Experiments were conducted on the same principle as that used for the conveyor and elevator, i.e., recording the time for complete passage of 100 pounds of feed from the bowl bottom to the discharge point. A record of these experiments is given in Appendix 3. Table 7A shows the passage time for 100 pounds of material at various settings, and Table 7B gives the equivalent pounds-per-hour passage rate.

TABLE 7A

Time (Minutes) per 100 Pounds Passing Parts Feeder

Regulator Setting		40	45	50	55	60	65	70	80
Size	Sp gr								
6 inch	3.1			Too large for feeder					
4 inch	2.6			6.7		4.7	3.7	3.2	1.2
2 1/2 to 2 in.	2.6	8.3	6.9	5.7		4.3	3.3	3.1	2.8
2 to 1 1/2 in.	2.6	9.3		6.7	5.0	4.6	4.2	3.8	3.3
1 1/2 to 1 in.	2.6	9.7	7.5	6.5	4.8	4.0		3.7	3.3
1 to 3/4 in.	2.6	12.7	10.6	8.1	6.5	5.6		5.0	4.6
3/4 in. to 4 m	3.1	10.5	8.5	7.3	5.9	5.3		4.2	3.5
4 to 20 mesh	2.7	19.7		15.3		9.8		7.0	5.2
-4 mesh	2.7	32.0				13.2			8.5

TABLE 7B.

Equivalent Pounds Per Hour Passing Parts Feeder

Regulator Setting		40	45	50	55	60	65	70	80
Size	Sp gr								
6 inch	3.1			Too large for feeder					
4 inch	2.6			900		1285	1637	1895	2400
2 1/2 to 2 in.	2.6	723	876	1043		1410	1800	1908	2160
2 to 1 1/2 in.	2.6	600		900	1200	1310	1440	1600	1800
1 1/2 to 1 in.	2.6	622	804	923	1242	1500		1635	1800
1 to 3/4 in.	2.6	472	565	740	930	1065		1200	1310
3/4 in. to 4 m	3.1	574	705	820	1025	1138		1440	1722
4 to 20 mesh	2.7	304		391		615		858	1156
-4 mesh	2.7	187				452			706

The maximum size of piece which could be handled by this feeder was found to be approximately 4 inches, and then only at relatively high rates. Below this size, the capacity was found to decrease with decreasing fragment or particle size. The effect of specific gravity may be observed by comparing the results on material that is 1 to 3/4 inch and has a sp gr of 2.6, with those for 3/4 in. to 4 mesh and a sp gr of 3.1. The pounds-per-hour rates for the latter are higher for each regulator setting. The finest material tried was minus-4-mesh. Material below this size would be better handled by the Vibra-Screw feeder.

The discharge rate for vibrating feeders is, in general, altered by the total weight resting on the vibrating mechanism. The effect of weight of material in the bowl of the parts feeder was assessed by means of three experiments as shown in Table 8. The method employed was to collect samples (for a specific time period) of material being discharged from the feeder when under heavy load, approximately half unloaded, and almost empty. Sample weights were calculated to pound-per-hour rates. In order that reasonably accurate samples be obtained, only material of 3/4-inch and less was used. This method of sampling can only be applied to lump materials if long sampling times are used. For the two more granular feeds -- 3/4 inch to 4 mesh and 4 to 20 mesh -- the results are consistent (with one exception, "4 to 20 mesh, setting 40, heavy load") and show a decrease in capacity as the weight on the mechanism is decreased. Results with the minus-4-mesh show a higher capacity at the mid-load level except for "setting 40, light load".

It was assumed that with coarse feed, damp material would behave in similar fashion as in the conveyor and elevator, and, if fines were present, that this machine could not handle damp feed. Two rough trials with damp lump confirmed that there would be no substantial change in discharge rate.

TABLE 8

Effect of Feed Load on Discharge Rate of Parts Feeder
(Pounds per Hour)

Regulator Setting			40	45	50	55	60	70	80
Size	Sp gr	Load							
3/4 in. to 4 mesh	3.1	Heavy	688	780	977	1205	1380	1530	1980
		Medium	556	735	943	1155	1215	1456	1815
		Light	330	502	690	990	1110	1396	1705
4 to 20 mesh	2.7	Heavy	308		480		862	1090	1465
		Medium	375		476		830	972	1080
		Light	354		435		532	730	746
-4 mesh	2.7	Heavy	158				502		840
		Medium	262				618		982
		Light	376				474		690

Vibra-Screw Feeder

(1) Description: The standard unit sits on a steel base plate, 36 by 20 inches. The model used in the experiments has been mounted on rubber-tired casters for ease of mobility. On the base plate are: 1) a 1/3-horse power motor and General Electric Polydine variable speed drive; 2) a steel feed chamber approximately 8 by 8 inches and 6 inches high, set on rubber cushions, to which discharge tubes of various size may be firmly attached; 3) side supports which carry the feed hopper, also set on rubber cushions. The hopper — a 3-cubic-foot, stainless steel cylinder, 20 inches in diameter and 18 inches high, and having a bottom sloping toward the discharge point — is located directly over the feed box, to which it is connected by a flexible 6-inch rubber tube.

For each size of discharge tube there is a narrow conveying screw which extends across the feed box and through the tube. This has the effect of carrying feed from the box into the tube, and preventing feed from packing along the tube bottom. Discharge tubes of 2-inch, 1-inch and 3/4-inch diameter are used for various capacity requirements.

Control is achieved by varying the Polydine Drive between units of 0 and 10. Power may be picked up from any 110-volt, 60-cycle, alternating-current outlet.

(2) Action: In operation, a system of V-belts from the drive causes both the hopper and the feed box with attached tube to vibrate, and the screw to rotate. Thus, material in the hopper is kept in motion toward the feed box, and material in the feed box in motion toward the discharge tube. The manufacturer undertakes that there is less than 2% deviation in discharge rate by this feeder, whether the hopper is full or nearly empty.

(3) Experiments and Results: Because this equipment is designed for feeding comparatively fine material at a constant rate, only minus-4-mesh and smaller sizes were used in the experiments. Minimum, medium and maximum feed rates were checked with the hopper full and nearly empty (to assess the effect of weight in the hopper on discharge from the discharge point). Because the manufacturer had indicated that the feeder should operate satisfactorily with damp feed, experiments were made to examine this possibility.

Three sizes of discharge tube were used in the experiments. For each run, the weight discharging in 60 seconds was obtained 3 times at 5-minute intervals, and the average was calculated. A complete record is given in Appendix 4. The results are summarized in Table 9 for the 2-inch, Table 10 for the 1-inch, and Table 11 for the 3/4-inch tube. Feed rates from as low as 7 pounds per hour to as high as 2 tons per hour are shown to be obtainable with this equipment. The feeder became plugged on all damp material containing fine powder, but operated satisfactorily on a 10-to 28-mesh sample at 5% moisture.

The effect of specific gravity was not as pronounced with this feeder as it was with the other machines, but in general higher discharge rates were obtained with the heavier materials. Capacity did not drop off sharply with finer particle size, as it did with the other machines.

The effect of weight of material in the feed hopper was not satisfactorily settled by the group of experiments recorded in Tables 9, 10, and 11. The method applied indicated that in some cases a higher and in others a lower discharge rate would be obtained. The differences tend to be more pronounced on material of 28 mesh or smaller size. This may be due, in part, to the sampling accuracy which can be seen in Appendix 4 to vary most widely in the finer sizes, especially at low discharge rates. In an experiment designed to resolve this factor, a series of samples was taken over the period that a full hopper was gradually emptying. The results appear in Table 12.

TABLE 9

Average Feeding Rates, 2-Inch Tube

Regulator Setting			0			5			10		
Hopper Level			High	Low	% Diff	High	Low	% Diff	High	Low	% Diff
Dry (pounds per hour)											
Size	Sp gr	% Water									
-4 m	2.7		255	255	0	1440	1500	+4	2760	2820	+2
-10 m	2.7		240	240	0	1360	1380	+1	2520	2520	0
-10 m	4.4			360			2040			3960	
-28 m	2.7		225	240	+6	1320	1440	+8	2340	2280	-3
-48 m	4.4		255	240	-6	1440	1500	+4	2700	2700	0
Damp (pounds per hour, dry basis)											
-4 m	2.7	5			Plugs						
10 to 28 m	2.7	5	147	152	+3	883	874	-1	1517	1691	+10
-10 m	2.7	5			Plugs						
-28 m	2.7	11			Plugs						
-28 m	2.7	5			Plugs						

TABLE 10

Average Feeding Rates, 1-Inch Tube

Regulator Setting		0			5			10		
Hopper Level		High	Low	% Diff	High	Low	% Diff	High	Low	% Diff
Dry (pounds per hour)										
Size	Sp gr									
-10 m	2.6	40			202			360		
-10 m	2.7	42	41	-2	240	255	+6	450	480	+6
-10 m	4.4		68			375			720	
-28 m	2.7	39	41	+5	210	225	+7	420	420	0
-48 m	4.4	46	49	+6	240	250	+4	450	480	+6

TABLE 11

Average Feeding Rates, 3/4-Inch Tube

Regulator Setting		0			5			10		
Hopper Level		High	Low	% Diff	High	Low	% Diff	High	Low	% Diff
Dry (pounds per hour)										
Size	Sp gr									
-10 m*	2.7	8.3	8.0	-3.6	50.4	52.5	+4.0	97.8	98.8	+1.0
-10 m	4.4		12.9			76.3			146.8	
-28 m	2.7	7.5	7.8	+3.8	42.2	40.3	-4.5	61.7	76.8	+19.7
-28 m	2.6	6.9	6.4	-7.2	40.3	39.7	-1.5	76.0	78.2	+2.8
-48 m	4.4	7.9	8.0	+1.3	41.2	45.8	+7.9	70.4	80.4	+12.5

*At 5% moisture this material plugged the feeder.

TABLE 12

Feed Rate at Various Hopper Levels for Vibra-Screw Feeder
(-28 mesh Nepheline Syenite, Controller 5,
1-inch Discharge Tube)

Hopper Level	Time Sample Taken	Pounds per Hour Discharging
High	9:25 a.m.	210
↓	9:35 "	210
	9:45 "	210
	9:55 "	222
	10:05 "	210
	10:15 "	210
	10:25 "	212
Empty	10:28 "	-

The one sharp deviation at 9:55 a.m. suggested that sampling accuracy was most probably behind the variations indicated in Tables 9 to 11. It is difficult to cut into and out of a stream of rock particles with split-second timing.

An experiment was made to check the precision with which the feeder could be reset to deliver a specified weight. The procedure was to set the feeder at approximately a 50-pound-per-hour rate, increase it to 75 pounds per hour, and finally to 100 pounds per hour. The controller was then returned to the initial setting, the second setting, and the final setting, in turn. Samples were taken at each stage. The results, as indicated in Table 13, show that the feeder may be reset at a determined rate with fair accuracy. The discrepancy decreases as the feed rate increases.

TABLE 13

Return to Former Setting, for Vibra-Screw Feeder
(-28 mesh Nepheline Syenite, 1-inch Tube)

Regulator Setting	First Setting (lb/hr)	Resetting (lb/hr)
0.75	49.1	51.5
1.60	75.1	76.8
2.20	100.3	100.0

A further consistency trial was made using minus-10-mesh syenite (see Table 1). The feeder was set to discharge at a rate of 75 pounds per hour through the 1-inch discharge tube. Several checks over a 30-minute period indicated that the 75-pound-per-hour rate was closely maintained. It was of interest that on this material the required control setting was 4.70 for the 75-pound-per-hour rate, as compared with 1.60 for minus-28-mesh nepheline syenite (Table 13).

DISCUSSION

The four types of vibrating units have a wide range of versatility. Although they do not fill the requirements perfectly, they go a long way toward meeting the conditions stipulated. All are easily moved from place to place and readily integrated with processing equipment. All are easy to clean. All are reasonably constant in delivery rates over a wide range of material size, although the transporting equipment does not handle fines as well as it does granular feeds.

With the exception of the Vibra-Screw feeder, moisture to approximately the amount that can be absorbed by the mineral surfaces may be tolerated, and improves performance on materials containing fines. Free moisture shakes out under the influence of vibration and forms a liquid layer on the transporting surface. This acts to defeat the action of the machine. The Vibra-Screw feeder plugs up on all damp, fines-containing material, but will handle granular materials at low moisture content.

With the exception of the Vibra-Screw feeder, which is designed to deliver at a constant rate, capacity is influenced by the bulk density of the material being moved. Higher bulk densities usually produce higher capacities, although anomalies occur. Due to the experimental method used, actual working capacities of the conveyor, elevator, and parts feeder would be in the order of 1.5 times the figures shown.

Conveying rates for minus-4-mesh material on the elevator were sharply lower than for the same feed on the conveyor. In Table 14, a comparison is made between the two machines. Since a cross-section of the elevator trough is approximately one-half that of the conveyor trough, the experimental figures for the elevator have been doubled for the purpose of this table only.

As indicated, the elevator performance on the coarser feeds compares favourably with that of the conveyor, taking into account the 10-degree slope. When fines are present, the elevator performance drops off sharply in comparison with that of the conveyor. It was inferred that an elevator with a rectilinear cross-section similar to that of the conveyor, and with a 5-degree slope, would perform better on fine materials.

The effect of load in the bowl of the parts feeder is pronounced. It would be advantageous to assure a constant weight of material in the bowl when operating the machine.

TABLE 14

Comparison of Conveyor and Elevator
(Pounds per hour, maximum rate)

		Conveyor		Elevator
Slope (degrees)		0	7.0	10.0
Size	Sp gr			
2 to 1 1/2 in.	2.6	1314	1260	1120
3/4 in. to 4 mesh	3.1	2573	1890	1850
3/4 in. to 4 mesh	4.4	4275	3030	1780
-4 mesh	2.7	1310	1242	124
-4 mesh	4.4	1722	1510	480
-10 mesh	2.7	1000	948	92
-10 mesh	4.4	1054	849	94
-28 mesh	2.7	340	125	19
-48 mesh	4.4	327	290	37

The Vibra-Screw feeder was shown to be reliable in delivering at a constant rate. For a given material, it may be reset on the controller to produce a desired feed rate.

CONCLUSIONS

The four vibrating devices examined were shown to have a broad range of application to the movement of bulk raw materials, and to be appropriate for connecting process units in a controlled continuous operation.

Capacity is relatively low on all four devices when dry powder forms part of the feed. This is reversed (except for the Vibra-Screw feeder) when a small amount of moisture is present, but vibrating equipment will not function properly on material having an excess of moisture. The Vibra-Screw feeder will not handle damp material containing fines but will function on damp, granular feed.

Capacity is influenced by the bulk density of the material being handled. Actual working capacities for the conveyor, elevator, and parts feeder would be from 1.3 to 1.8 times the experimental figures.

For elevating, a slope of 5 degrees would be preferable to 10 degrees, and any additional units should have a 5-degree slope.

The Vibra-Screw feeder will provide a reliable, constant feed rate on fine-sized dry material.

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APPENDIX 1

Conveyor Experiments

1) Conveyor Flat, Feed Dry

	Regulator Setting	Time/ 100 lb (min)	Lb/hr	Remarks
Material: Magnesite Size: 6 inch Sp gr: 3.1	50 85 120	10.9 3.7 2.3	550 1635 2565	Slow Steady Fast, steady
Material: Sandstone Size: 2 1/2 to 2 inch Sp gr: 2.6	50 85 120	23.7 6.7 3.9	254 900 1557	Slow, some jamming Steady Fast, steady
Material: Sandstone Size: 2 to 1 1/2 inch Sp gr: 2.6	50 85 120	27.4 6.9 4.6	219 865 1314	Slow, some jamming Steady, slight delay at discharge Fast, steady
Material: Sandstone Size: 1 1/2 to 1 inch Sp gr: 2.6	50 85 120	34.4 6.8 4.0	175 887 1500	Very slow, some jams Steady Fast, steady
Material: Sandstone Size: 1 to 3/4 inch Sp gr: 2.6	50 85 120	38.2 6.4 3.1	157 945 1995	Very slow Steady Fast, steady
Material: Fluorite Size: 3/4 in. to 4 mesh Sp gr: 3.1	50 85 120	37.5 5.2 2.3	160 1160 2573	Very slow Steady Fast, steady
Material: Barite Size: 3/4 in. to 4 mesh Sp gr: 4.4	50 85 120	16.2 2.8 1.4	370 2155 4275	Even Even Even
Material: Limestone Size: 4 to 20 mesh Sp gr: 2.7	50 85 120	42.6 4.5 1.7	140 1340 3474	Very slow, drags Steady Fast, steady
Material: Limestone Size: -4 mesh Sp gr: 2.7	50 85 120	50.0 9.2 4.6	120 653 1310	Slow, steady, even Steady Fast, steady

1) Conveyor Flat, Feed Dry (Continued)

	Regulator Setting	Time/ 100 lb (min)	Lb/hr	Remarks
Material: Barite	50	46.3	130	Even
Size: -4 mesh	85	7.8	766	Bunches up
Sp gr: 4.4	120	3.5	1722	Bunches up
Material: Limestone	50	62.7	96	Bunches, forms steps
Size: -10 mesh	85	18.3	328	Bunches, forms steps
Sp gr: 2.7	120	6.0	1000	Bunches badly
Material: Barite	50	124.0	48	Even, forms waves
Size: -10 mesh	85	13.5	444	Tends to bunch
Sp gr: 4.4	120	5.7	1054	Even
Material: Limestone	50			Piles up, blocks
Size: -28 mesh	85	60.0	100	Segregates, blocks
Sp gr: 2.7	120	17.6	340	Bunches, waves
Material: Barite	50	194.0	31	Steps, irregular
Size: -48 mesh	85	31.8	188	Steps or waves
Sp gr: 4.4	120	18.3	327	Steps

2) Conveyor Sloped, Feed Dry, Controller 120

	Slope (degrees)	Time/ 100 lb (min)	Lb/hr	Remarks
6 inch Magnesite Sp gr: 3.1	3.5 7.0	2.7 3.1	2250 1916	Fast, steady Fast, steady
2 to 1 1/2 in. Sandstone Sp gr: 2.6	3.5 7.0	4.4 4.8	1380 1260	Fast, steady Fast, steady
3/4 in. to 4 mesh Fluorite Sp gr: 3.1	3.5 7.0	2.8 3.2	2120 1890	Fast, steady Fast, steady
3/4 in. to 4 mesh Barite Sp gr: 4.4	3.5 7.0	1.9 2.0	3167 3030	Even Even
-4 mesh Limestone Sp gr: 2.7	3.5 7.0	5.5 4.8	1090 1242	Fast, even Fast, even
-4 mesh Barite Sp gr: 4.4	3.5 7.0	3.6 4.0	1664 1510	Waves Uneven
-10 mesh Limestone Sp gr: 2.7	3.5 7.0	7.3 6.3	820 948	Bunches Bunches
-10 mesh Barite Sp gr: 4.4	3.5 7.0	8.8 7.1	678 849	Bunches Bunches, uneven
-28 mesh Limestone Sp gr: 2.7	3.5 7.0	31.6 48.0	189 125	Slow, steady Steps, bunches
-48 mesh Barite Sp gr: 4.4	3.5 7.0	20.0 20.7	300 290	Even, steps Bunches, steps

3) Conveyor Flat, Feed Damp

	Regulator Setting	% Water	Time/ 100 lb (min)	Lb/hr	Remarks
Material: Limestone Size: -4 mesh Sp gr: 2.7	50 65 85 120	2.8	 30.0 5.5 4.2	 200 1097 1438	Won't move Slow, doesn't clear Steady, slow at end Steady, fast
Material: Limestone Size: -10 mesh Sp gr: 2.7	65 85 120	4.0	30.0 8.3 2.5	200 720 2400	Slow, doesn't clear Steady Steady, fast
Material: Limestone Size: -28 mesh Sp gr: 2.7	65 85 120	4.8	18.5 7.5 2.8	324 804 2120	Slow Steady Steady, fast
Material: -28 mesh Limestone	120	7.0	3.0	2000	Steady, fast

4) Conveyor Sloped, Feed Damp, Controller 120

	Slope (deg)	% Water	Time/ 100 lb (min)	Lb/hr	Remarks
-4 mesh Limestone Sp gr: 2.7	3.5 7.0	2.8 2.8	2.2 2.5	2765 2400	Steady, fast Steady
-10 mesh Limestone Sp gr: 2.7	3.5 7.0	4.0 4.0	2.8 3.5	2120 1730	Steady, fast Steady
-28 mesh Limestone Sp gr: 2.7	3.5 7.0	4.8 4.8	3.3 3.5	1800 1730	Steady, fast Steady

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APPENDIX 2

Elevator Experiments

1) Feed Dry

	Regulator Setting	Time/ 100 lb (min)	Lb/hr	Remarks
Material: Sandstone Size: 2 1/2 to 2 inch Sp gr: 2.6	10 13 17			Pieces wedge Pieces wedge Pieces wedge
Material: Sandstone Size: 2 to 1 1/2 inch Sp gr: 2.6	9 10 13 17	 21.4 11.9 10.7	 280 504 560	Pieces wedge Wedges unless careful Wedges unless careful Less wedging
Material: Fluorite-Barite Size: -2 inch Sp gr: 3.7	12 13 15 17	 21.0 14.0 11.3	 286 428 532	Hardly moves Fines slow movement Packs, spills Packs, spills
Material: Sandstone Size: 1 1/2 to 1 inch Sp gr: 2.6	9 13 17	27.4 12.7 8.7	219 470 692	Bunches Even, steady Even, steady
Material: Sandstone Size: 1 to 3/4 inch Sp gr: 2.6	9 13 17	93.5 15.8 13.1	64 380 456	Slow, poor unloading Steady, even Steady, even
Material: Fluorite Size: 3/4 in. to 4 mesh Sp gr: 3.1	9 13 17	 17.6 6.5	 340 925	Doesn't unload Steady, even Steady, even
Material: Barite Size: 3/4 in. to 4 mesh Sp gr: 4.4	11 14 17	15.4 8.2 6.8	390 728 890	Steady, even Steady, even Steady, even
Material: Limestone Size: -4 mesh Sp gr: 2.7	11 14 17	132.5 112.5 97.3	45 53 62	Slow, segregates Slow, segregates Poor unloading
Material: Barite Size: -4 mesh Sp gr: 4.4	11 14 17	37.7 28.6 24.9	159 210 240	Bunches Slow, even Slow, even

1) <u>Feed Dry</u> (continued)

	Regulator Setting	Time/ 100 lb (min)	Lb/hr	Remarks
Material: Limestone	11	227.3	26	Slow, segregates
Size: -10 mesh	14	177.3	34	Slow, segregates
Sp gr: 2.7	17	130.0	46	Slow, segregates
Material: Barite	11	529.2	11	Bunches badly
Size: -10 mesh	14	202.5	30	Some bunching
Sp gr: 4.4	17	127.8	47	Some bunching
Material: Limestone	9	61.5	97	Some bunching
Size: 14 to 20 mesh	13	20.5	292	Slow, even
Sp gr: 2.7	17	14.5	413	Some segregation
Material: Limestone	11			Blocks
Size: -28 mesh	14	800.0	7.5	Slow, segregates
Sp gr: 2.7	17	620.0	9.6	Slow, segregates
-28 mesh sand	17	21.0	300.0	Slight bunching
Sp gr: 2.6				
Material: Barite	11	910.0	6.6	Bunches badly
Size: -48 mesh	14	409.2	12.2	Some bunching
Sp gr: 4.4	17	320.0	18.7	Some bunching

2) Feed Damp

	Regulator Setting	% Water	Time/ 100 lb (min)	Lb/hr	Remarks
Material: Fluorite-Barite Size: -2 in. Sp gr: 3.7	11 14 17	3			Stalls Stalls Stalls
Material: Limestone Size: -10 mesh Sp gr: 2.7	11.5 14.0 17.0	4	14.5 9.0 6.3	414 666 923	Steady, even Steady, even Steady, some bunching
Material: Limestone Size: -28 mesh Sp gr: 2.7	11.5 14.0 17.0	4.8	23.0 11.0 7.2	261 545 837	Bunches, blocking Steady, even Steady, even
Material: Limestone Size: -28 mesh Sp gr: 2.7	11.5 14.0 17.0	7.0			Mats, blocks Mats, blocks Mats, blocks

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APPENDIX 3

Parts Feeder Experiments

1) Feed Dry

	Regulator Setting	Time/ 100 lb (min)	Lb/hr	Remarks
Material: Magnesite Size: 6 inch				Falls off ledge
Material: Sandstone Size: 4 inch Sp gr: 2.6	40			Fails to unload
	50	6.7	900	Steady, even
	60	4.7	1285	Steady, even
	65	3.7	1637	Steady, even
	70	3.2	1895	Steady, even
	80	1.2	2400	Steady, even
Material: Sandstone Size: 2 1/2 to 2 inch Sp gr: 2.6	40	8.3	723	Erratic
	45	6.9	876	Erratic
	50	5.7	1043	Steady, even
	60	4.3	1410	Steady, even
	65	3.3	1800	Steady, even
	70	3.1	1908	Steady, even
	80	2.8	2160	Steady, even
Material: Sandstone Size: 2 to 1 1/2 inch Sp gr: 2.6	40	9.3	600	Erratic
	50	6.7	900	Steady, slow dumping
	55	5.0	1200	Steady, even
	60	4.6	1310	Steady, even
	65	4.2	1440	Steady, even
	70	3.8	1600	Steady, even
	80	3.3	1800	Steady, even
Material: Sandstone Size: 1 1/2 to 1 inch Sp gr: 2.6	40	9.7	622	Erratic, slow dumping
	45	7.5	804	Erratic, slow dumping
	50	6.5	923	Steady, even
	55	4.8	1242	Steady, even
	60	4.0	1500	Steady, even
	70	3.7	1635	Steady, even
	80	3.3	1800	Steady, even

1) Feed Dry (Continued)

	Regulator Setting	Time/ 100 lb (min)	Lb/hr	Remarks
Material: Sandstone Size: 1 to 3/4 inch Sp gr: 2.6	40	12.7	472	Erratic, slow dumping
	45	10.6	565	Erratic, slow dumping
	50	8.1	740	Tapering
	55	6.5	930	Steady, even
	60	5.6	1065	Steady, even
	70	5.0	1200	Steady, even
	80	4.6	1310	Steady, even
Material: Fluorspar Size: 3/4 to 4 mesh Sp gr: 3.1	40	10.5	574	Steady, tapering
	45	8.5	705	Steady, tapering
	50	7.3	820	Steady, tapering
	55	5.9	1025	Steady
	60	5.3	1138	Steady
	70	4.2	1440	Steady, even
	80	3.5	1722	Steady, even
Material: Limestone Size: 4 to 20 mesh Sp gr: 2.7	40	19.7	304	Segregates, slow dump
	50	15.3	391	Segregates, steady
	60	9.8	615	Segregates, steady
	70	7.0	858	Steady, even
	80	5.2	1156	Steady, even
Material: Limestone Size: -4 mesh Sp gr: 2.7	40	32.0	187	Segregates, slow dump
	60	13.2	452	Segregates, slow dump
	80	8.5	706	Segregates, slow dump

2) Effect of Weight in Bowl (Bowl Full at Start)

	Regulator Setting	Lb/hr		
		Start	Middle	End
Material: Fluorspar Size: 3/4 in. to 4 mesh Sp gr: 3.1	40	688	556	330
	45	780	735	502
	50	977	943	690
	55	1205	1155	990
	60	1380	1215	1110
	70	1530	1456	1396
	80	1980	1815	1708
Material: Limestone Size: 4 to 20 mesh Sp gr: 2.7	40	308	375	354
	50	480	476	435
	60	862	830	532
	70	1090	972	730
	80	1465	1080	746
Material: Limestone Size: -4 mesh Sp gr: 2.7	40	158	262	376
	60	502	618	474
	80	840	982	690

APPENDIX 4

Vibra-Screw Feeder Experiments

1) Feed Dry, 2-inch Tube

	Regulator Setting	Hopper Level	Samples (lb/hr, 5-min intervals) 1	2	3	Average
Material: Limestone Size: -4 mesh Sp gr: 2.7	0	High Low	255 255	255 255	255 255	255 255
	5	High Low	1440 1500	1440 1500	1440 1500	1440 1500
	10	High Low	2760 2820	2760 2820	2760 2820	2760 2820
Material: Limestone Size: -10 mesh Sp gr: 2.7	0	High Low	240 240	240 240	240 240	240 240
	5	High Low	1320 1380	1380 1380	1380 1380	1360 1380
	10	High Low	2520 2520	2520 2520	2520 2520	2520 2520
Material: Barite Size: -10 mesh Sp gr: 4.4	0	High Low	Not enough feed available 360	 360	 360	 360
	5	High Low	Not enough feed available 2040	 2040	 2040	 2040
	10	High Low	Not enough feed available 3960	 3960	 3960	 3960
Material: Limestone Size: -28 mesh Sp gr: 2.7	0	High Low	225 240	225 240	225 240	225 240
	5	High Low	1320 1440	1320 1440	1320 1440	1320 1440
	10	High Low	2340 2280	2340 2280	2340 2280	2340 2280
Material: Barite Size: -48 mesh Sp gr: 4.4	0	High Low	255 240	255 240	255 240	255 240
	5	High Low	1440 1500	1440 1500	1440 1500	1440 1500
	10	High Low	2700 2700	2700 2700	2700 2700	2700 2700

2) Feed Damp, 2-inch Tube

	Regulator Setting	% Water	Hopper Level	Samples(lb/hr, 5-min intervals) 1	2	3	Average
Material: Limestone Size: -4 mesh Sp gr: 2.7	0	5	High Low	- 171	- 171	- 171	- 171
	5	5	High Low	-	- Plugs	-	-
Material: Limestone Size: 10 to 28 mesh Sp gr: 2.7	0	5	High Low	157 142	142 157	142 157	147 152
	5	5	High Low	883 855	883 883	883 883	883 874
	10	5	High Low	1370 1652	1594 1710	1594 1710	1517 1691
Material: Limestone Size: -10 mesh Sp gr: 2.7	0	5	High Low	-	- Plugs	-	-
Material: Limestone Size: -28 mesh Sp gr: 2.7	0	11	High Low	-	- Plugs	-	-
Material: Limestone Size: -28 mesh Sp gr: 2.7	0	5.6	High Low	-	- Plugs	-	-

3) Feed Dry, 1-Inch Tube

	Regulator Setting	Hopper Level	Samples(lb/hr, 5 min intervals) 1	2	3	Average
Material: Limestone Size: -10 mesh Sp gr: 2.7	0	High Low	43 41	41 42	41 41	42 41
	5	High Low	240 255	240 255	240 255	240 255
	10	High Low	450 480	450 480	450 480	450 480

3) Feed Dry, 1-Inch Tube (Continued)

	Regulator Setting	Hopper Level	Samples (lb/hr, 5-min intervals)			
			1	2	3	Average
Material: Barite Size: -10 mesh Sp gr: 4.4	0	High Low	Not enough feed available 68	 68	 68	 68
	5	High Low	Not enough feed available 375	 375	 375	 375
	10	High Low	Not enough feed available 720	 720	 720	 720
Material: Syenite Size: -10 mesh Sp gr: 2.6	0	High Low	- 40	- 40	- 40	- 40
	5	High Low	- 202	- 203	- 202	- 202
	10	High Low	- 363	- 363	- 363	- 363
Material: Limestone Size: -28 mesh Sp gr: 2.7	0	High Low	39 41	39 41	39 41	39 41
	5	High Low	210 225	210 225	210 225	210 225
	10	High Low	420 420	420 420	420 420	420 420
Material: Barite Size: -48 mesh Sp gr: 4.4	0	High Low	46 49	46 49	46 49	46 49
	5	High Low	240 250	240 250	240 250	240 250
	10	High Low	450 480	450 480	450 480	450 480

4) Feed Dry, 3/4-Inch Tube

	Regulator Setting	Hopper Level	Samples (lb/hr, 5-min intervals) 1	2	3	Average
Material: Limestone Size: -10 mesh Sp gr: 2.7	0	High	8.4	8.4	8.0	8.3
		Low	8.0	8.0	8.0	8.0
	5	High	50.7	50.3	50.3	50.4
		Low	52.5	52.5	52.5	52.5
	10	High	97.5	97.5	98.5	97.8
		Low	99.4	99.4	97.5	98.8
Material: Barite Size: -10 mesh Sp gr: 4.4	0	High	Not enough feed available			
		Low	13.1	13.1	12.6	12.9
	5	High	Not enough feed available			
		Low	76.0	76.8	76.8	76.3
	10	High	Not enough feed available			
		Low	148.0	146.7	145.8	146.8
Material: Limestone Size: -28 mesh Sp gr: 2.7	0	High	7.5	7.5	7.5	7.5
		Low	7.5	8.0	8.0	7.8
	5	High	42.2	42.2	42.2	42.2
		Low	41.2	40.3	38.4	40.3
	10	High	62.0	61.6	61.6	61.7
		Low	77.7	77.7	75.0	76.8
Material: Nepheline syenite Size: -28 mesh Sp gr: 2.6	0	High	7.1	7.1	6.6	6.9
		Low	6.6	6.1	6.6	6.4
	5	High	40.3	40.3	40.3	40.3
		Low	39.9	39.9	39.4	39.7
	10	High	76.0	76.0	76.0	76.0
		Low	79.5	77.3	77.8	78.2
Material: Barite Size: -48 mesh Sp gr: 4.4	0	High	8.4	7.8	7.5	7.9
		Low	7.8	8.4	7.8	8.0
	5	High	43.1	41.2	39.4	41.2
		Low	46.9	45.6	45.0	45.8
	10	High	71.2	68.9	71.2	70.4
		Low	81.1	80.6	79.3	80.4

Note: The -10 and -28 mesh limestone at 5% moisture plug the feeder.

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