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BLENDING FREE-FLOWING SEEDS WITH BIN FLOW CONTROL DEVICES

A PROGRESS REPORT

by

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Considerable effort has been expended in the study of blending and the development of blending methods, both for the chemical industries (FISHER, 1960) and for seeds (DOUGHERTY, 1963; MASCARENHAS, 1961; PARKMAN, 1963). But mixing/blending is still an empirical art with little foundation of scientific analysis (BROTHMAN, WOLLAN and FELDMAN, (1945). Little theory is available to support a quantitative and systematic approach to blending of solids. Most equipment has been developed for specific purposes; few blending devices are available for a wide variety of applications (KIRK and OTHMER, 1952).

Blending is essentially a unit operation in which energy is applied to a mass of material to alter the initial particle arrangement to obtain a more desirable particle arrangement (BROTHMAN, WOLLAN and FELDMAN, 1945). Kinetic energy promotes mixing of gases, while liquids are mixed by a similar phenomenon. But, solid particles have no such forces to cause a free, random flow and distribution (FISHER, 1960). Mixing/blending of solid particles can be considered as extending the surface of separation or interface between two or more zones of unblended materials, by the migration of particles of each material, until the surface of separation between them extends down to the level of individual particles (BROTHMAN, WOLLAN and FELDMAN, 1945). Thus, blending involves movement or intermingling of materials in all directions so as to result in or approach homogeneity. Force, either gravitational or mechanical, must be applied to a mass of solid particles to cause them to intermingle and blend. Fluid convection is a useful term to denote use of an imposed force for this purpose (KIRK and OTHMAR, 1952).

Although the distinction between free-flowing and non-free-flowing solid materials is largely arbitrary (BARRE, 1958), friction among particles affects the flowability of a material and its classification as either free-flowing or non-free-flowing. A free-flowing material flows steadily and consistently as individual particles; non-free-flowing materials tend to flow 'en masse' or as ågglomerated particles (CARR, 1965). This flow behavior influences the type of force which must be applied to seeds in order to cause individual seeds to migrate in a random manner and produce an acceptable blend.

Free-flowing granular solids have been observed to flow as individual particles, even through a fine orifice (CARR, 1965); 'unmixing' and, to some extent, reblending have been observed in the flow of such materials from a bin. Gravity has been the predominant force used to move individual particles, although physical characteristics also exert a considerable influence on total movement In addition to the flow from a bin caused by gravitational influences on solid particles, vertical and lateral pressures are developed within a mass of solid particles such as a loaded bin (HAMILTON and NELSON, 1964; JENIKE, 1954; LEE, 1963).

These pressures, in large masses such as grain elevator tanks, change and create pressure shifts which have damaged walls or require additional wall strength at the time the tank is emptied (KETCHUM, 1919). A perforated cylinder device has been successfully used in elevator tanks to withdraw grain in a manner which eliminated dangerous pressure buildups (*Grain and Feed Journal*, July 8, 1964).

Critical review of these other reports appears to establish that: (a) free-flowing solid particles with similar physical characteristics will flow from a bin and change their relative position or arrangement in a random manner under the influence of gravity; (b) pressures develop in definite, predictable patterns within a mass of solid particles, and (c) systems of bin discharge orifices can be used to relieve (or use) these pressures. This raises an interesting question: Can a combination or modification of these characteristics be used to develop an efficient, effective blending system that can be economically integrated into commercial seed processing operations?

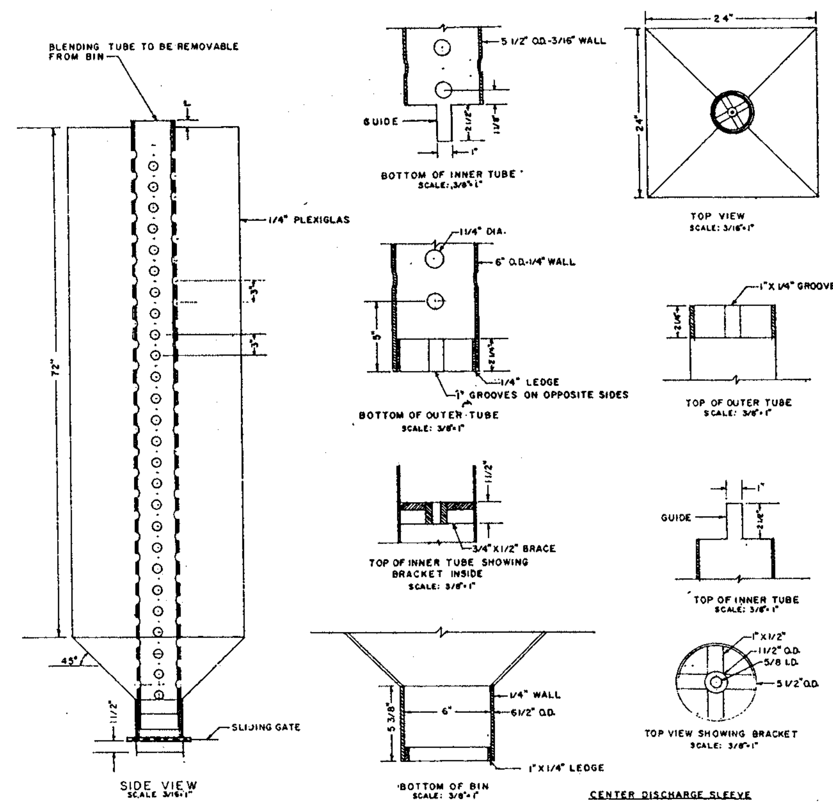
To investigate this possibility, a research program was initiated largely through the efforts of S. F. Rollin of the United States Department of Agriculture. Entitled 'Improved Techniques and Equipment for Uniformly Blending Seed Lots', it is a cooperative project with the Field Seed Institute of North America, the Consumer and Marketing Service, USDA and the Transportation and Facilities Research Division, USDA, United States Department of Agriculture. Work under this project is being conducted by the Seed Technology Laboratory, Mississippi Agricultural Experiment Station, Mississippi State University.

METHODS AND MATERIALS

Design of bins and withdrawal systems

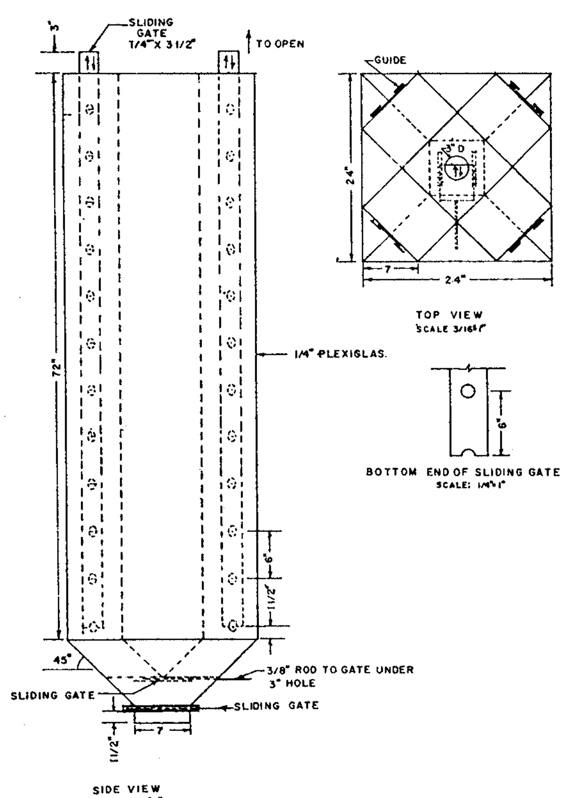
Two-dimensional bin flow test models gave flow patterns that were correct cross-sections of flow in a semi-infinite mass moving in 2 dimensions, but were not satisfactory for representing flow in a 3-dimensional bin (Collins and Yin, 1965). Further, it has been shown that lateral pressures due to depth of material do not materially increase after the depth of the bin reaches 2.5 to 3 times its width (Ketchum, 1919). On these bases, the present study employed 3-dimensional model bins 2 feet thick, 2 feet wide and 6 feet deep, exclusive of the hopper bottom. The bins were constructed of transparent plastic so that flow patterns could be observed visually.

Withdrawal or discharge devices were designed to withdraw seed simultaneously from all possible horizontal locations in all vertical layers of the bin and

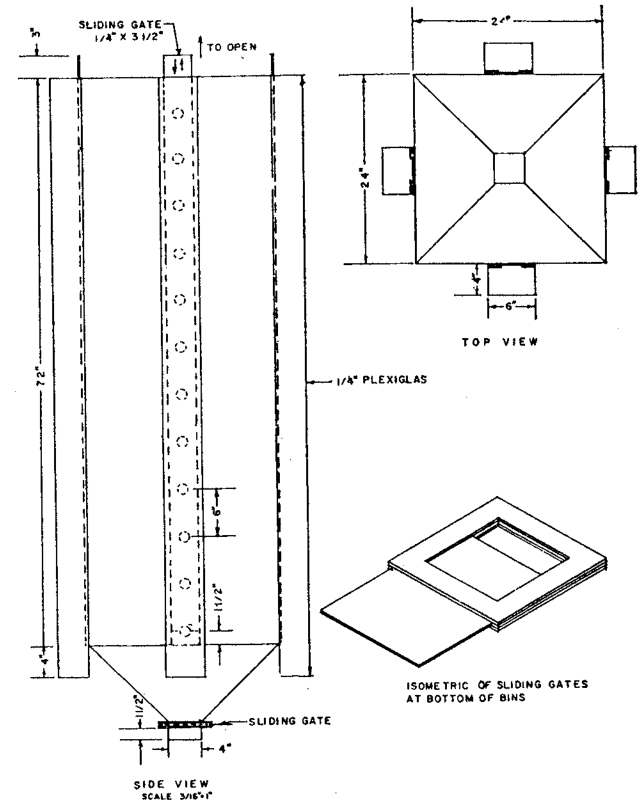


blend them together. Five configurations of the discharge devices were designed:

1. Center discharge sleeve (Figure 1)
   A cylinder containing a series of discharge orifices was installed in the center of the bin.
2. Corner sleeves (Figure 2)
   A vertical row of discharge orifices was installed in each of the 4 bin corners.
3. Center-of-side discharge (Figure 3)
   A vertical row of discharge orifices was installed in the center of each of the 4 sidewalls of the bin.
4. Perforated inner wall (Figure 4)
   Seed are removed from all vertical levels through 2 rows of orifices equally spaced down each side wall.



CORNER SLEEVES

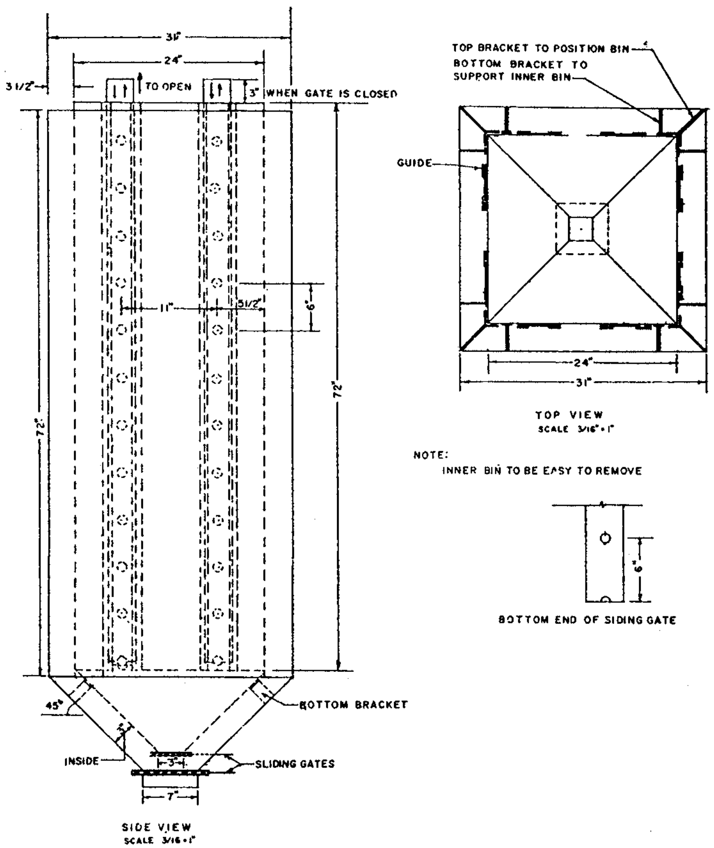


CENTER-OF-SIDE DISCHARGE

5. Center pressure-bridge sleeve (Figure 5)
   A cross-shaped device was installed inside the bin so that 8 vertical rows of discharge orifices removed seed midway between the bin sidewalls and bin center at each vertical level.

Evaluation procedures

The work was divided into two phases: first, the experimental bin discharge/blending devices were to be evaluated for blending efficiency; second, if encouraging results were obtained, the most promising device was to be carefully evaluated and redesigned in the light of the test results, and a unit suitable for full-scale testing in a commercial processing plant would be designed. Only work under the first phase is included in this preliminary report.

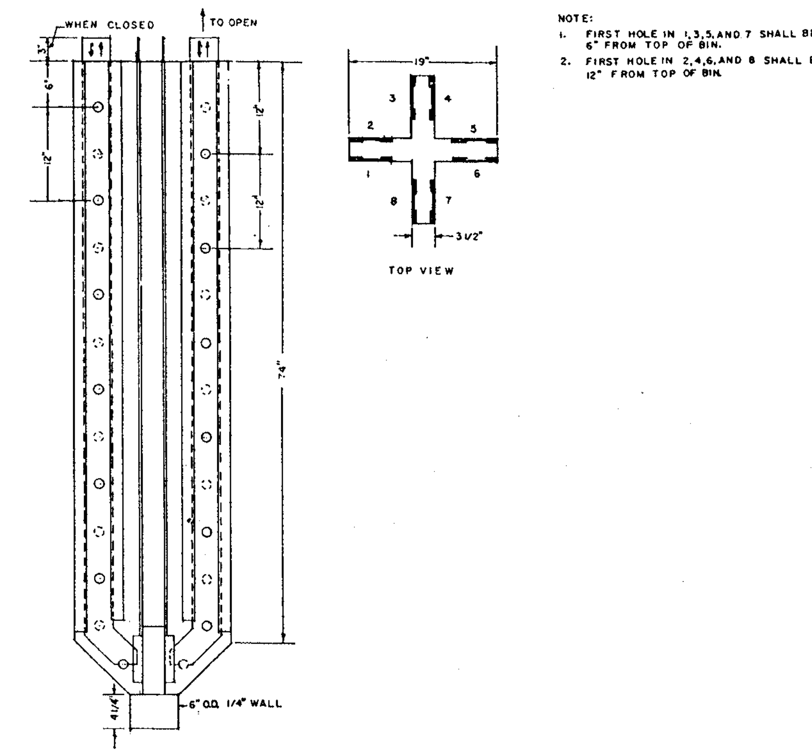


PERFORATED INNER WALL

Initial tests of blending efficiency were made with colored 3/16-inch diameter plastic Bakelite polyethylene particles whose similar physical and flow characteristics should eliminate variations due to varying flow characteristics of the material. This would simulate blending different lots of the same kind of seed, and permit positive evaluation of blending efficiency.

In tests, the experimental blending bin was loaded with six separate successive one-foot-deep layers of plastic particles, each layer of a different color, to simulate blending of six different components loaded into the bin in sequence. This procedure allowed evaluation of the relative flow of material from six different levels of the bin.

After the bin was loaded, the series of discharge/blending orifices was opened,



CENTER PRESSURE-BRIDGE SLEEVES

NOTE:
THIS UNIT TO FIT INSIDE BIN FOR CENTER DISCHARGE SLEEVE

so that particles discharged simultaneously from the six layers of the bin, and flowed together into a single discharge spout. Five-hundred-gram samples, approximately the size of samples used for noxious weed seed examinations on seed of similar size, were taken at timed intervals to represent one sample from each of the twenty 50-pound bags filled from a bin load.

The samples were then separated into the six individual colors (each representing a definite layer of the bin) by an electronic color sorter, and percentages by weight of each color were determined. The composition of each sample representing a single bag of material was compared with the computed bin average, and with that of all other bags filled from the entire bin load.

In addition to utilizing the colored plastic particles, three types of tests using seed were made: (a) two seed kinds with similar physical characteristics were blended; (b) two seed kinds widely dissimilar in physical characteristics; and (c) blending crop seed containing an inseparable weed seed with crop seed containing no weed seed.

Results and Discussion

Plastic Particles

Some of the tests using plastic particles have been completed on some devices and evaluated by the chi square goodness-of-fit test programmed on a computer. When all data have been obtained, the I.S.T.A. heterogeneity tests will be applied to measure uniformity and accuracy of blending.

Results obtained thus far with experiments using plastic particles indicate:

1. Material in a bin loaded with six different lots of components cannot be blended satisfactorily by a single pass through a device which incorporates a series of discharge orifices to simultaneously withdraw seed from all levels from:

a. Center of the bin
b. Corners of the bin
c. Center of the side walls of the bin
d. Midway between the side walls and center of the bin

Different devices exhibited different flow patterns; but, in general, variability increased in consecutive samples taken as material flowed from the bin.

2. A second consecutive pass through the blending device greatly improved the degree of blending but still did not produce an acceptable blend.

3. A third consecutive pass through the blending device produced a remarkable degree of homogeneity, both among the 20 samples and as compared with the expected percentages of each component based on weights of each component loaded into the bin. Chi square P values for some devices were greater than .995 for all samples when compared with the expected values.

4. A fourth consecutive pass through the blending device produced results similar to the third pass, except that some samples exhibited slightly wider variations from the expected values.

Tables 1–8 show differences between expected and observed component percentages after 1, 2, 3, and 4 consecutive passes through the device employing discharge orifices in the center of the bin side walls. Chi square P values are also shown.

TABLE 1. Difference between expected and actual percentages of each of 6 components of the blend in 20 consecutive samples. Center tube discharge 1; pass through the system

Sample No.	Lower Layer *white* Diff. from 18.8% Expect.	Layer 2 *black* Diff. from 16.25% Expect.	Layer 3 *red* Diff. from 16.25% Expect.	Layer 4 *green* Diff. from 16.25% Expect.	Layer 5 *yellow* Diff. from 16.25% Expect.	Top Layer *orange* Diff. from 16.25% Expect.	X^2 P Value
1	+ 8.8	− 5.65	+ .75	− 1.35	+ 2.45	− 5.65	.25−.10
2	+ 4.3	− 3.45	+ .65	− .85	− 3.35	+ 2.75	.75−.5
3	+ 4.0	− 1.15	− 3.15	− 1.95	− 2.25	+ 4.45	.75−.5
4	+ 0.6	+ 3.75	− 4.05	− .95	− 2.25	+ 2.95	.75−.5
5	− 1.6	+ 3.95	− 3.35	− 2.15	− 3.25	+ 6.05	.5−.25
6	− 5.8	+ 7.05	− 3.15	− 3.25	− 1.75	+ 6.85	.25−.10
7	− 7.4	+ 7.75	− .65	− 3.05	− 3.85	+ 7.25	.05−.025
8	− 9.8	+ 5.45	+ .45	− 3.15	− .75	+ 7.85	.05−.025
9	−14.9	− 2.85	+ 7.35	− .45	+10.05	+ .65	.005
10	−12.6	− .25	+ 5.45	− 1.85	+15.15	− 6.05	.005
11	−15.0	− 7.55	+ 3.45	+ 4.05	+21.85	− 6.85	.005
12	−14.9	− 6.35	+ .45	+16.15	+13.75	− 9.15	.005
13	−15.0	− 6.95	+10.05	+15.65	− 2.25	−11.55	.005
14	−15.0	− 8.15	+29.25	+15.05	− 5.05	−16.25	.005
15	− 9.5	+ 8.75	+30.55	− 2.95	−10.85	−16.25	.005
16	+ 2.75	+18.65	+ .85	−14.85	−16.25	−16.25	.005
17	+ 2.33	+ 8.05	+16.25	−16.17	−16.25	−16.25	.005
18	+ 3.58	24.35	−11.45	−16.25	−16.25	−16.25	.005
19	+ 4.93	+12.45	−13.75	−16.20	−16.25	−16.25	.005
20	+ 6.37	− .65	−15.05	−16.20	−16.25	−16.25	.005

TABLE 2. Difference between expected and actual percentages of each of 6 components of the blend in 20 consecutive samples. Center tubė discharge; 2 passes through the system

Sample No.	Lower Layer *white* Diff. from 18.8% Expect.	Layer 2 *black* Diff. from 16.25% Expect.	Layer 3 *red* Diff. from 16.25% Expect.	Layer 4 *green* Diff. from 16.25% Expect.	Layer 5 *yellow* Diff. f from 16.25% Expect.	Top Layer *orange* Diff. from 16.25% Expect.	X^2 P Value
1	+2.4	+ .45	− .45	−1.05	−1.05	− .35	.995−.99
2	+ .3	+ .55	+ .55	− .95	− .05	− .45	.995
3	+ .2	− .45	+ .25	− .35	+ .45	− .05	.995
4	+ .4	+ .45	+ .05	−1.05	+ .45	− .35	.995
5	− .8	+ .45	+ .95	− .65	+ .55	− .65	.995
6	− .5	+1.05	+1.15	− .85	− .25	− .55	.995
7	−5.8	+4.65	+ .25	−1.05	+ .75	+1.05	.75−.5
8	−1.0	+3.15	+ .35	− .55	− .55	−1.55	.975−.95
9	−1.5	+2.85	+1.05	− .85	− .15	−1.55	.975−.95
10	−2.2	+2.05	+1.75	+ .25	− .65	−1.25	.975
11	−2.3	+3.15	+ .05	− .05	+ .15	−1.05	.975−.95
12	−3.7	+3.15	+1.25	− .35	+ .95	−1.35	.90
13	−5.7	+3.25	+1.55	+ .15	+ .65	+ .05	.9−.75
14	−1.4	+1.95	+1.55	− .55	− .45	−1.15	.99−.975
15	−4.8	+3.65	− .75	−1.55	−1.75	−5.05	.75−.5
16	−5.2	+2.45	−1.65	− .55	−1.55	−2.48	.9−.5
17	−1.9	+1.15	−2.65	− .55	−2.45	+6.35	.75-.5
18	+0.2	− .55	−2.85	− .25	−1.75	+5.15	.9−.75
19	+2.1	− .55	−2.25	− .15	−2.55	+3.25	.90
20	+4.4	−2.15	−2.25	− .55	−2.25	−2.85	.9−.75

TABLE 3. Difference between expected and actual Percentages of each of 6 components of the blend in 20 consecutive samples. Center tube discharge; 3 passes through the system

Sample No.	Lower Layer *white* Diff. from 18.8% Expect.	Layer 2 *black* Diff. from 16.25% Expect.	Layer 3 *red* Diff. from 16.25% Expect.	Layer 4 *green* Diff. from 16.25% Expect.	Layer 5 *yellow* Diff. from 16.25% Expect.	Top Layer *orange* Diff. from 16.25% Expect.	X^2 P Value
1	+0.90	−0.65	+0.15	−0.45	−0.45	+0.35	.995
2	+0.60	−0.25	+0.35	−0.95	−0.15	+0.35	.995
3	+0.40	−0.05	+0.65	−0.75	+0.35	−0.75	.995
4	+0.60	+0.85	+0.85	−1.05	−0.15	−0.15	.995
5	+1.30	−0.25	+0.85	−1.05	−0.15	−0.15	.995
6	+1.30	+0.85	+0.55	−1.15	+0.25	−0.65	.995
7	+0.50	−0.25	+1.15	−1.15	+0.65	−0.65	.995
8	−1.20	−0.15	+1.55	− .85	+1.05	−0.45	.995
9	+0.20	+0.85	+0.95	−1.05	+0.05	−0.95	.995
10	−0.60	+1.85	+0.45	−0.95	−0.45	−0.15	.995
11	−0.70	+2.15	+0.35	−0.85	−0.65	−0.25	.995
12	−0.80	+1.75	+0.45	−1.45	+0.35	−0.55	.995
13	−1.40	+3.05	−0.35	−0.95	−0.55	+0.15	.99−.975
14	−1.70	+3.05	+0.15	−1.45	−0.45	+0.35	.975−.95
15	−2.40	+3.45	+0.45	−1.05	−0.55	+0.05	.975−.95
16	−1.70	+3.85	+0.05	−1.05	−0.45	−0.65	.95−.90
17	+0.30	+3.75	−0.05	−0.15	−0.75	+0.05	.975−.95
18	−2.50	+2.05	−0.55	+1.25	−0.75	+0.35	.99−.95
19	−2.00	+1.35	−0.95	+1.05	−0.75	+1.25	.99−.975
20	−1.90	+1.05	−0.55	+0.45	−0.45	+1.25	.995

TABLE 4. Difference between expected and actual percentages of each of 6 components of the blend in 20 consecutive samples. Center tube discharge; 4 passes through the system

Sample No.	Lower Layer *white* Diff. from 18.8% Expect.	Layer 2 *black* Diff. from 16.25% Expect.	Layer 3 *red* Diff. from 16.25% Expect.	Layer 4 *green* Diff. from 16.25% Expect.	Layer 5 *yellow* Diff. from 16.25% Expect.	Top Layer *orange* Diff. from 16.25% Expect.	X^2 P Value
1	+1.40	−0.15	+0.35	−0.85	+0.05	−0.75	.995
2	+1.70	−0.45	+0.55	−0.95	−0.25	−0.55	.995
3	+1.30	−0.15	+0.85	−0.85	+0.15	−1.15	.995
4	+1.30	+0.15	+0.85	−0.95	−0.15	−1.05	.995
5	+1.20	+1.15	+0.05	−.085	−0.15	−0.85	.995
6	+1.50	+0.15	+0.85	−0.15	+0.05	−0.15	.995
7	+1.30	+1.15	−0.15	−0.85	−0.15	−0.15	.995
8	+1.20	+1.85	−0.15	−1.05	−0.15	−1.05	.995−.99
9	+0.20	+1.95	−0.05	−0.85	+0.05	−0.15	.995
10	+0.50	+0.75	+0.15	−1.15	+0.05	−0.25	.995
11	−0.80	+1.65	+1.35	−1.05	−0.35	−0.85	.995−.99
12	+0.10	+2.35	−0.55	−0.85	−0.65	−0.65	.990
13	−0.70	+1.85	−0.05	−0.65	−0.55	+0.05	.995
14	−0.90	+2.65	−0.35	−0.65	−0.35	−0.45	.995−.99
15	−0.80	+2.75	−0.25	−0.55	−0.65	−0.65	.99−.975
16	−2.10	+2.75	−0.65	+0.45	−0.95	+0.35	.99−.975
17	0.00	+0.15	−0.55	+0.45	−0.65	+0.65	.995
18	−1.10	−0.35	−0.45	+0.65	−0.15	+1.25	.995
19	−0.60	+0.15	−0.15	+0.35	−0.85	+1.25	.995
20	−1.20	+0.65	−0.65	+0.25	+0.05	+1.05	.995

TABLE 5. Difference between expected and actual percentages of each of 6 components of the blend in 20 consecutive samples. Center-of-sidewall discharge; 5 pass through the system

Sample No.	Lower Layer *white* Diff. from 10.2% Expect.	Layer 2 *black* Diff. from 17.96% Expect.	Layer 3 *red* Diff. from 17.96% Expect.	Layer 4 *green* Diff. from 17.96% Expect.	Layer 5 *yellow* Diff. from 17.96% Expect.	Top Layer *orange* Diff. from 17.96% Expect.	X^2 P Value
1	+ 7.8	− 5.56	− 1.26	− 1.66	− 0.06	+ 0.94	.25−.10
2	− 1.4	+ 1.04	+ 0.24	+ 0.94	− 3.46	+ 2.34	.95−.90
3	− 1.9	+ 2.74	− 1.96	+ 0.84	− 5.56	+ 5.84	.50−.25
4	− 3.0	+ 3.74	+ 0.04	− 0.46	− 6.06	+ 5.84	.50−.25
5	− 3.3	+ 5.24	+ 0.14	− 3.56	− 5.36	+ 6.94	.25−.10
6	− 6.0	− 1.56	+ 3.74	− 1.86	− 1.86	+ 7.69	.25−.10
7	− 5.1	− 0.86	+ 5.64	− 3.06	− 0.16	+ 3.44	.50−.25
8	− 6.4	− 3.76	+ 2.74	− 2.46	+ 9.14	+ 0.84	.10−.05
9	− 6.8	− 6.06	+ 1.94	+ 3.14	+16.44	− 8.66	.005
10	− 7.1	− 7.96	− 1.96	+ 7.34	+24.64	−14.96	.005
11	− 7.7	−10.66	− 1.66	+14.04	+20.84	−14.86	.005
12	− 7.8	− 8.86	+10.04	+ 7.94	+15.34	−16.66	.005
13	− 8.1	− 0.86	+ 8.64	+14.24	+ 3.34	−17.36	.005
14	− 8.2	+18.34	− 0.86	+15.04	− 6.66	−17.66	.005
15	− 8.2	+26.74	− 2.96	+20.64	−15.56	−17.76	.005
16	+ 1.7	+19.04	+21.14	− 6.56	−17.66	−17.76	.005
17	+13.5	+20.94	+14.64	−13.36	−17.86	−17.76	.005
18	+40.1	+21.84	+14.46	−15.86	−17.86	−17.86	.005
19	+77.3	− 9.56	−15.06	−17.36	−17.94	−17.93	.005
20	+87.8	−16.76	−17.46	−17.76	−17.86	−17.95	.005

TABLE 6. Difference between expected and actual percentages of each of 6 components of the blend in 20 consecutive samples. Center-of-sidewall discharge; 2 passes through the system

Sample No.	Lower Layer *white* Diff. from 10.2% Expect.	Layer 2 *black* Diff. from 17.96% Expect.	Layer 3 *red* Diff. from 17.96% Expect.	Layer 4 *green* Diff. from 17.96% Expect.	Layer 5 *yellow* Diff. from 17.96% Expect.	Top Layer *orange* Diff. from 17.96% Expect.	X^2 P Value
1	+1.70	−0.26	−0.16	+0.04	−0.06	−1.26	.995
2	−0.70	−0.16	+0.74	−0.06	+0.24	+0.04	.995
3	−1.20	+0.04	−0.26	+0.54	+0.04	+0.84	.995
4	−1.90	−0.36	+0.16	+0.34	+0.84	+1.04	.995—.99
5	−1.70	+0.04	−0.16	+0.94	+0.84	+1.44	.99—.975
6	−1.70	−0.26	+0.44	+0.54	+0.84	+0.14	.995
7	−2.30	+0.04	+0.44	+1.04	+1.54	−0.66	.99—.975
8	−1.90	+0.24	+0.54	+1.54	+2.54	−3.26	.995—.99
9	−0.70	+1.04	+0.34	+2.24	+1.34	−4.26	.95—.90
10	+0.70	+0.34	+0.84	+2.04	+1.64	−5.66	.90—.75
11	+1.40	+0.84	−0.06	+1.84	+1.44	−5.56	.90—.75
12	+1.70	+0.44	+0.84	+1.04	+0.54	−4.76	.90—.75
13	−0.00	+0.34	+1.04	+1.34	+1.14	−3.66	.975—.95
14	−3.30	+0.74	+0.74	+1.44	+1.54	−1.06	.95—.90
15	−3.80	−0.16	+1.04	+0.84	+1.44	+0.48	.90—.75
16	−3.80	+0.04	+0.84	−1.46	−0.56	+2.94	.90—.75
17	−3.00	−0.16	+0.34	−1.46	−1.06	+5.44	.75—.50
18	−3.20	+0.24	+0.74	−1.56	−0.86	+5.04	.90—.75
19	−2.60	+0.84	+0.04	−1.46	−1.86	+5.04	.90—.75
20	+3.20	−0.36	−1.16	−2.16	−2.96	+3.34	.90—.75

TABLE 7. Difference between expected and actual Percentages of each of 6 components of the blend in 20 consecutive samples. Center-of-sidewall discharge; 3 passes through the system

Sample No.	Lower Layer *white* Diff. from 10.2% Expect.	Layer 2 *black* Diff. from 17.96% Expect.	Layer 3 *red* Diff. from 17.96% Expect.	Layer 4 *green* Diff. from 17.96% Expect.	Layer 5 *yellow* Diff. from 17.96% Expect.	Top Layer *orange* Diff. from 17.96% Expect.	X^2 P Value
1	−1.30	+0.34	−0.16	+0.64	+0.94	−0.56	.995
2	−1.20	−0.16	+0.44	+0.44	+0.24	+0.24	.995
3	−1.10	+0.34	+0.44	+0.54	+0.34	−0.56	.995
4	−1.20	+0.44	−0.06	+0.54	+0.54	−0.36	.995
5	−1.00	+0.24	+0.44	+0.44	+0.54	−0.56	.995
6	−1.30	+0.44	−1.56	+0.34	+0.24	−0.56	.995
7	−1.10	+0.44	+0.44	+0.44	+0.44	−0.66	.995
8	−0.80	−0.36	−0.26	+1.04	+1.14	−0.66	.995
9	−1.20	+1.24	−0.16	+1.14	+0.94	−1.96	.995
10	−1.40	+1.24	−0.06	+0.44	+0.84	−1.16	.995
11	−1.10	+0.54	+0.54	+0.94	+0.54	−1.46	.995
12	−1.10	+0.24	+0.34	+0.44	+0.94	−0.86	.995
13	−1.30	+0.44	+0.44	+0.64	+0.54	−0.76	.995
14	−1.30	−0.06	+0.74	+0.94	+0.64	−0.86	.995
15	−1.60	−0.06	+0.44	+1.14	+0.34	−0.46	.995
16	−0.90	+0.54	+0.44	+0.14	+0.74	−0.96	.995
17	−1.50	+0.94	+0.94	+0.14	−0.56	+0.14	.995
18	−1.40	+0.84	+0.44	+0.34	+0.24	−0.56	.995
19	−1.50	+1.54	+0.24	−0.56	+0.44	−0.26	.995
20	−0.30	−0.46	−0.66	+0.44	+0.14	+0.84	.995

TABLE 8. Difference between expected and actual percentages of each of 6 components of the blend in 20 consecutive samples. Center-of-sidewall discharge; 4 passes through the system

Sample No.	Lower Layer *white* Diff. from 10.2% Expect.	Layer 2 *black* Diff. from 17.96% Expect.	Layer 3 *red* Diff. from 17.96% Expect.	Layer 4 *green* Diff. from 17.96% Expect.	Layer 5 *yellow* Diff. from 17.96% Expect.	Top Layer *orange* Diff. from 17.96% Expect.	X^2 P Value
1	−1.00	+0.24	+0.54	+0.84	+0.84	−1.46	.995
2	−0.90	+0.44	−0.26	−0.26	+1.34	−0.36	.995
3	−1.10	−0.06	+1.04	+0.64	+0.74	−1.26	.995
4	−1.10	−0.06	+0.54	+0.64	+0.64	−0.56	.995
5	−0.60	−0.56	+0.24	+0.44	+1.14	−0.66	.995
6	−0.70	−0.36	−0.06	+0.64	+1.34	−0.86	.995
7	−0.70	−0.86	+0.64	+0.94	+0.74	−0.86	.995
8	−1.10	+0.94	+0.04	+0.64	+0.64	−1.16	.995
9	−0.90	+0.34	+0.44	+0.24	+0.24	−0.26	.995
10	−0.20	−0.36	+0.34	+0.14	+1.54	−1.36	.995
11	−1.10	−0.16	+0.64	+0.84	+0.94	−0.66	.995
12	−0.90	−0.96	+0.64	+0.44	+1.14	−0.46	.995
13	−0.80	−1.06	+0.44	+0.74	+1.44	−0.76	.995
14	−0.90	+0.14	+0.94	+0.24	+0.64	−1.06	.995
15	−0.80	−0.36	+0.34	+0.54	+0.84	−0.56	.995
16	−0.60	−0.26	+0.84	+0.14	+0.54	−0.66	.995
17	−0.20	+0.26	−0.76	+0.04	+1.94	−1.16	.995
18	−1.20	−1.46	+0.34	+1.04	+0.64	−0.76	.995
19	−1.00	+0.04	+0.54	+1.24	+0.24	−1.16	.995
20	+21.40	−5.46	−4.16	−3.56	−4.36	−4.26	.005

Seed with dissimilar physical characteristics

Since physical characteristics of seed exert a strong and limiting influence on seed flow through a gravity system, tests of blending efficiency using corn and sorghum as widely dissimilar seed were conducted on 3 devices. The purpose of this test was to determine if a blending device could overcome the controlling influence of wide differences in seed physical characteristics on their movement in a gravity-flow blending system. The bin under test was first filled to 53% capacity with corn, and then the remaining 47% was filled with sorghum. The bin load of seed was then passed through each device for five consecutive passes.

TABLE 9. Average variation of actual from expected % corn in 10 consecutive samples drawn after 1, 2, 3, 4, and 5 consecutive passes through each of 3 experimental blending devices

Blending device	Average sample variation from expected % corn after consecutive pass number				
	1	2	3	4	5
Center tube	−4.7%	−6.5%	−2.5%	−2.2%	−3.3%
Center-of-side	+4.8	+0.5	+1.6	+0.4	+2.0
Corner	−4.0	+3.8	+2.2	+3.3	+4.2

Ten samples were taken from the stream of discharging material during each pass.

Table 9 shows average variation of the percent of corn in the samples from the expected percentage for the total bin.

Each time the mixture flowed down a spout or into the bin, the sorghum separated from the corn. Composition of a given area within the blending bin thus changed from time to time, and affected the blend results by changing the kind of seed flowing from the bin at a given level. Also, this prevented any marked improvement in blending by consecutive passes through the system.

These data and observations on separation and stratification of seed during blending operations indicate that physical characteristics of seeds are an important limiting factor in seed blending. Before any reliable or predictable blending system is developed, it may be necessary to establish the relative effects of varying physical characters and the extent to which seed may differ and still be blended.

Weed seed and crop seed

To evaluate the efficiency with which weed seeds of similar flow characteristics can be blended into crop seeds, morning glory seed (*Ipomea* spp.) were blended into sorghum seed with the center-of-side wall discharge device. Forty pounds of sorghum seed containing 20,000 *Ipomea* seed were loaded into the approximate center of a total bin load of 1,000 pounds of morning glory-free sorghum seed. The bin load was then passed through the blending device for 3 consecutive passes. On the third pass, a series of 20 samples were taken, to represent a sample from each of the twenty 50-pounds bag in the bin. The number of morning glory seed in each sample are shown in Table 10.

TABLE 10. Morning glory seed blended into sorghum seed Expected blend: 20 per pound; center-of-side discharge; device samples after 3 consecutive passes through the device

Consecutive sample no.	Morning glory seed per pound	Diff. from expected blend (seed per pound)
1	20.6	+0.6
2	15.1	−4.9
3	13.1	−5.9
4	20.2	+0.2
5	26.2	+6.2
6	25.2	+5.2
7	14.1	−5.9
8	17.7	−2.3
9	15.5	−4.5
10	20.9	+0.9
11	15.0	−5.0
12	14.4	−5.6
13	19.3	−0.7
14	14.0	−6.0
15	16.6	−3.4
16	16.0	−4.0
17	14.0	−6.0
18	19.9	−0.1
19	14.5	−5.5
20	19.1	−0.9
Average	17.6	

FURTHER WORK PLANNED

Present data appear very promising for free-flowing seeds. Evaluation of the 5 systems will continue, to determine the most efficient device and the design modifications necessary to make it suitable for commercial inter-lot and intra-lot blending.

Three areas of further research appear, necessary both to develop these devices and to add to our knowledge of seed blending:

1. A careful study of the influence of physical characteristics of seeds on their behaviour in a blending system must be made, to establish limitations of seed differences in which a blend is possible and could be reasonably expected.
2. The configuration of the bin itself must be redesigned to obtain complete discharge of the total bin load in a uniform flow pattern.

3. A study of the physical and economic limitations and characteristics of a blending system which could be incorporated into a commercial continuous-flow processing operation should be made.

SUMMARY

Solid -solid blending techniques and devices used in modern commercial seed operations are actually products of limited research and unknown theory. A basic concept of events which occur during the mixing/blending process, and the relationship of each to the climax blend, is necessary to develop a blending system applicable to the many needs of a modern seed operation.

The Seed Technology Laboratory, Mississippi Agricultural Experiment Station, Mississippi State University, has underway a research study entitled 'Improved Techniques and Equipment for Uniformly Blended Seed Lots". Its purpose is to investigate and develop one or more devices which can lend itself to a commercial operation and produce a homogeneous mixture/blend within prescribed tolerances.

Because of the lack of continuity within a lot of seed, a device was designed that would bring all vertical one-foot layers of the bin load into random motion at the same time and same speed. Five configurations of the discharge devices were designed:

1. Center discharge sleeve (Figure 1)
   A cylinder containing a series of discharge orifices in the center of the bin.
2. Corner sleeves (Figure 2)
   A vertical row of discharge orifices in each of the 4 bin corners.
3. Center-of -side discharge (Figure 3)
   A vertical row of discharge orifices in the center of each of the 4 side walls of the bin.
4. Perforated inner wall (Figure 4)
   Seed are removed from all vertical levels through 2 rows of orifices equally spaced down each side wall.
5. Center pressure-bridge sleeve (Figure 5)
   A cross-shaped device inside the bin so that 8 vertical rows of discharge orifices remove seed midway between the bin side walls and bin center at each vertical level.

The initial study was conducted with 3/16-inch diameter plastic Bakelite polyethylene particles differing only in color, to simulate blending different lots of the same kind of seed.

Each one-foot-layer (exclusive of the hopper bottom) was filled with a different color. The discharge orifices were opened to a predetermined clearance to obtain blending/mixing. After discharging, the mass of particles was collected in a holding bin and then recirculated through the system. Four passes through the system were sampled, and 20 samples from each pass were analyzed. The Chi Square (Goodness of fit) values of probability are given in Tables 1-8 for two of the systems.

The first pass through the system did not produce an acceptable blend. The second consecutive pass greatly improved the blending efficiency, but the theoretical degree of homogeneity was not ascertained.

The third consecutive pass through the system produced a high degree of homogeneity; some systems produced Chi Square Values greater than .995 for all samples when

compared to the theoretical values. A fourth consecutive pass produced results similar to the third pass, but some variability resulted between some samples and their expected values.

In addition, three types of tests using seed were made: (a) Blending two seed kinds with similar physical characteristics; (b) blending two seed kinds widely dissimilar in physical characteristics; (c) blending crop seed containing an inseparable weed seed with crop seed containing no weed seed. Results of two of these tests (b. c) are given in tables IX and X respectively.

Present data appear very promising for free-flowing seed. Continuation of the study is necessary to refine the system and make it suitable for commercial inter- and intra-lot blending.

Resume

Le mélange de semences a écoulement facile a l'aide de dispositifs de réglage du flux dans la trémie

Actuellement, les techniques et dispositifs de mélange de solides entre eux, employés dans le traitement commercial des semences, sont des produits de recherche limitée et de théorie ignorée. Une notion fondamentale des processus qui se déroulent au cours du procédé de mélange et la relation de chacun d'entre eux avec le point culminant du mélange, est indispensable afin de pouvoir mettre au point un système de mélange adapté aux exigences multiples du traitement moderne des semences.

Le Laboratoire de Technologie des Semences, Station de recherches agricoles de Mississippi, Université de l'Etat de Mississippi, a mis en route une étude expérimentale, intitulée 'Techniques et équipement perfectionnés pour le mélange uniforme de lots de semences'. Son but consiste à étudier et mettre au point un ou plusieurs dispositifs capables de fonctionner dans des conditions commerciales et de produire un mélange uniforme entre les limites de tolérance prescrites.

Comme il n'y a pas de continuité dans un lot de semences, on a mis au point un dispositif qui mettrait toutes les couches verticales d'un pied de la charge de la trémie en mouvement arbitriare, au même moment et à la même vitesse. Cinq configurations de dispositifs de décharge ont été construites:

1. Douille de décharge centrale (figure 1)
   Un cylindre contenant une série d'orifices de décharge au centre de la trémie.
2. Douille d'angle (figure 2)
   Une rangée verticale d'orifices dans chacun des 4 coins de la trémie.
3. Décharge au centre des côtés (figure 3)
   Une rangée verticale d'orifices de décharge au centre des 4 parois latérales de la trémie.
4. Paroi interne perforée (figure 4)
   Les semences sont déverseés de tous les niveaux verticaux à travers 2 séries d'orifices, uniformément espacés le long de chaque paroi latérale.
5. Douille centrale à pont de pression (figure 5)
   Un dispositif en forme de croix à l'intérieur de la trémie, disposé de sorte que 8 rangées verticales d'orifices de décharge déversent les semences à mi-chemin entre les parois latérales et le centre de la trémie à chaque niveau vertical.

L'étude préliminaire a été pratiqueé au moyen de particules plastiques de polyéthylène-bakélite, d'un diamètre de 3/16 inch et différant seulement de couleur, pour simuler le mélange des différents lots de la même espèce de semences.

Chaque couche d'un pied (excepté le fond de la trémie) fut remplie avec une couleur différente. Les orifices de décharge furent ouverts de sorte qu'un espace libre prédéterminé fut atteint pour le mélange. Après vidange, la masse des particules fut rassemblée dans une trémie d'attente, puis recirculée à travers le système. Les valeurs de probabilité Chi-carré (bonne adaptation) sont reprises aux tableaux 1 à 8 pour deux de ces systèmes.

Le premier passage à travers le système ne produisit pas de mélange acceptable. Le second passage consécutif améliora fortement l'éfficacité de mélange, mais le degré théorique d'homogénéité ne fut pas assuré. Le troisième passage consécutif à travers le système produisit un degré d'homogénéité élevé; certains systèmes donnaient des valeurs de Chi-carré supérieures à 0,995 pour tous les échantillons comparés aux valeurs théoriques. Un quatrième passage produisit des résultats similaires à ceux du troisième mais il y eut une certaine variabilité entre certains échantillons et leurs valeurs attendues.

En plus, trois types d'essai pour l'emploi des semences ont été effectués: a. le mélange de deux espèces de semences à caractéristiques physiques similaires; b. le mélange de deux espèces de semences à caractéristiques physiques fortement différentes; c. mélange de semences de plantes cultivées contenant des graines de mauvaise herbe inséparables, avec des semences de plantes de culture ne contenant pas de graines de mauvaises herbes. Les résultats de deux de ces essais (b, c) sont repris respectivement aux tableaux 9 et 10.

Les résultats obtenus jusqu'à présent paraissent très prometteurs pour des semences à écoulement facile. Il est nécessaire de continuer l'étude afin de perfectionner le système et de l'adapter au mélange commercial du même lot et de lots différents.

Zusammenfassung

Das Vermengen frei strömender Samen durch Vorrichtungen mit Mengenregelung im Behälter

Die bei modernen Behandlungen von Handelssaatgut gebräuchlichen Verfahren und Vorrichtungen zur Vermengung von festen Substanzen beruhen gegenwärtig noch auf beschränkten Forschungen und unbekannten Theorien. Eine gründliche Kenntnis der Vorgänge, die während der Vermengung verlaufen und ihres Zusammenhangs mit der erreichbaren Mischung ist erforderlich, um ein System der Vermengung zu entwickeln, das den zahlreichen Anforderungen der modernen Saatgutaufbereitung entspricht.

Im 'Seed Technology Laboratory' der Mississippi Experiment Station, Missisippi State University, ist eine Forschungsarbeit im Gange mit dem Titel 'Verbesserte Verfahren und Ausrüstungen für die einheitliche Vermengung von Saatgutpartien'. Ihr Zweck ist eine oder mehrere Vorrichtungen zu untersuchen und zu entwickeln, die