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Proceedings: 1969 Short Course for Seedsmen (Full Document)

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Proceedings

1969 SHORT COURSE for SEEDSMEN

April 21-April 24, 1969

SEED TECHNOLOGY LABORATORY

STATE COLLEGE MISSISSIPPI

Sponsored By The Mississippi Seedmen's Association

PROCEEDINGS

1969 Short Course for Seedsmen

April 21 - 24, 1969

Seed Technology Laboratory
Mississippi State University

State College, Mississippi

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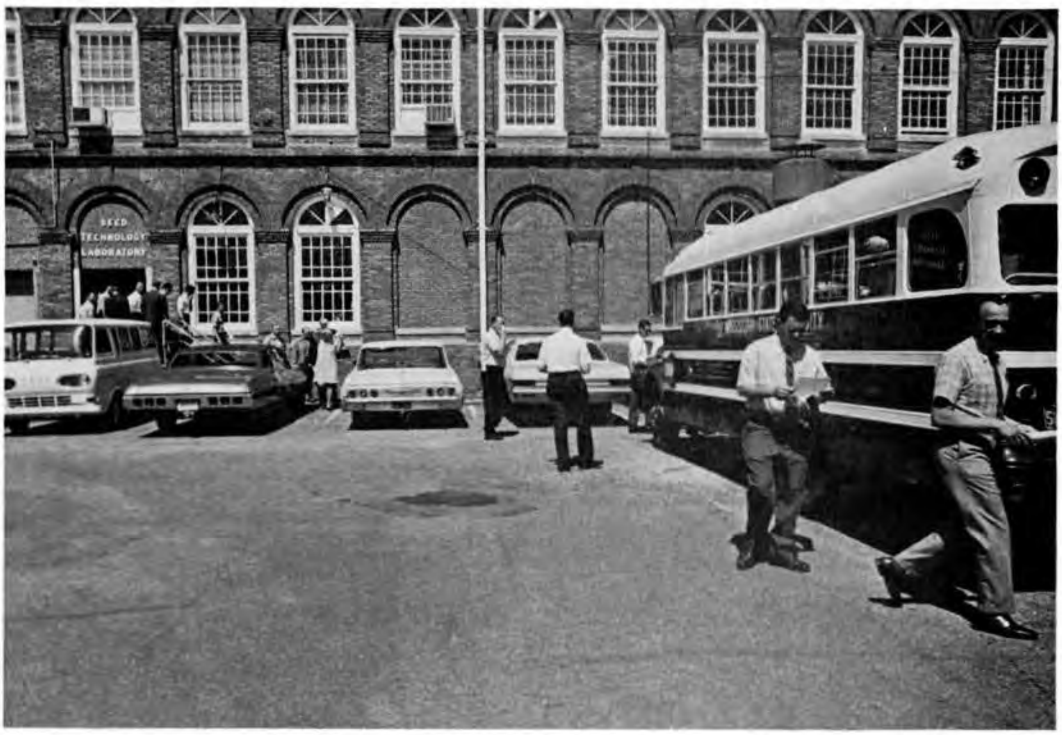

Bus Tours


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STAFF

SEED TECHNOLOGY LABORATORY

STATE COLLEGE, MISSISSIPPI

1. Dr. James C. Delouche . In Charge, Seed Technology Laboratory
2. Dr. C. Hunter Andrews . . . . Assistant Agronomist
3. Dr. G. Burns Welch . . . . Associate Agricultural Engineer
4. Dr. Kenneth Matthes . . . . Assistant Agricultural Engineer
5. A. H. Boyd, Jr. . . . . Assistant Agronomist
6. George M. Dougherty . . . . Assistant Agronomist
7. Charles C. Baskin . . . . Assistant Agronomist
8. James M. Beck . . . . Engineering Technician
9. Harold W. Byrd . . . . Assistant Agronomist
10. Charles Sciple . . . . Assistant Agronomist
11. Alice Perkins . . . . Laboratory Technician
12. Irene Caldwell . . . . Laboratory Technician
13. Lola Haire . . . . Laboratory Technician
14. Curtis Reed . . . . Technical Aide
15. Dero Kinard . . . . Technical Assistant
16. Jimmy Clardy . . . . Technical Aide
17. Lucy Carpenter . . . . Secretary
18. Gloria Boling . . . . Secretary
19. Gloria Cade . . . . Secretary

AID/M.S.U.- Brazil Contract
Rio de Janeiro, Brazil

20. Dr. Howard C. Potts . . . . Chief of Party
21. Dumont Douleyrette . . . . Assistant Agronomist

AID/M.S.U. - India Contract
New Delhi, India

22. Dr. Bill R. Gregg . . . . Chief of Party


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GRADUATE

AND

UNDERGRADUATE STUDENTS

1. R. Bhatkal . . . . India
2. Udai Ram Bishnoi . . . . .India
3. Luiz A. de Castro . . . . Brazil
4. Sylvia Chang . . . . Taiwan
5. Joe Johnson . . . . Mississippi
6. Roger Landers . . . . Illinois
7. Leticia Manzon . . . . Philippines
8. Sammie Newsom . . . . Mississippi
9. Bettaija Rajanna . . . . India
10. Prasoot Sittisroung . . . . Thailand
11. Charles Smith . . . . Mississippi
12. N. D. Toke . . . . India
13. Carlos Vechi . . . . .Brazil
14. Joann Wise . . . . .Louisiana

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GUEST SPEAKERS

1. Dr. H. Dean Bunch	Director International Programs in Agriculture and Forestry MSU State College, Miss.
2. Charles E. Vaughan	North Carolina State University and MSU Raleigh, North Carolina
3. Jim Henderson	A. T. Ferrell and Company Saginaw, Michigan
4. Z. A. Stanfield	Funk Brothers Seed Company Bloomington, Illinois
5. W. S. Acheson	Gustafson Manufacturing Co. Hopkins, Minnesota
6. Bill Wallace	Hagan Manufacturing Company Memphis, Tennessee
7. Bowen Campbell	Campbell Industries Des Monies, Iowa

PROGRAM SCHEDULE
Monday, April 21

8:00 - 12:00	REGISTRATION - Seed Technology Laboratory
	COFFEE, COKES, DOUGHNUTS - Furnished all week, courtesy of equipment manufacturers and their representatives.
10:00 - 11:30	TOURS OF UNIQUE UNIVERSITY FACILITIES (Transportation Furnished)
12:00	LUNCH
1:25	"Thru Knowledge and Action" Presiding: C. H. Andrews Welcomes and Introduction
2:00	SEED POWER IS OUR THING - Charles E. Vaughan, North Carolina State University (and MSU), Raliegh, North Carolina
3:00	COFFEE, COKES, DOUGHNUTS
3:30	EQUIPEMENT DEMONSTRATIONS - Staff and Manufacturers' Representatives and SEED TESTING EXHIBITS - Staff
7:00	BAR-B-QUE DINNER, University Cafeteria Courtesy, Mississippi Seed Improvement Association and Mississippi Seedsmen's Association

Tuesday, April 22

8:25	"Thru Attention to Basics" Presiding: James C. Delouche
8:30	BASIC SEED CLEANING: AIR-SCREEN CLEANERS - Jim Henderson, A. T. Ferrell and Company, Saginaw, Michigan
9:15	PRINCIPLES OF SEED SEPARATIONS - A. H. "Bill" Boyd, Jr., Staff
9:45	SEED SHAPE SEPARATIONS - G. M. Dougherty, Staff
10:00	COFFEE, COKES, DOUGHNUTS
10:30	TROUBLESHOOTING - Z. A. "Zeke" Stanfield, Funk Bros. Seed Co., Bloomington, Illinois
11:00	COMPLIANCE WITH SEED LAWS - Charles Sciple, Staff
11:30	SURFACE TEXTURE SEPARATIONS - C. Hunter Andrews, Staff
12:00	LUNCH
1:25	"Thru Maintenance of Quality" Presiding: Charles E. Vaughan
1:30	ESSENTIALS OF QUALITY CONTROL - James C. Delouche, Staff
2:15	PRACTICAL TESTS FOR SEED QUALITY - C. C. Baskin and H. W. Byrd, Staff
3:00	COFFEE, COKES, DOUGHNUTS
3:30	DEMONSTRATIONS OF SELECTED EQUIPMENT - Staff and Manufacturers' Representatives and SEED QUALITY CONTROL METHODS I

Wednesday, April 23

8:25	"Thru Greater Efficiency" Presiding: A. H. "Bill" Boyd, Jr.
8:30	MODERN SEED PACKAGING - W. S. "Bill" Acheson, Gustafson Manufacturing Co., Hopkins, Minnesota
9:10	PACKAGING MATERIALS - C. C. Baskin, Staff
9:30	DENSITY SEPARATIONS OF SEED - G. Burns Welch, Staff
10:00	COFFEE, COKES, DOUGHNUTS
10:30	SEED HANDLING AND CONVEYING - Bill Wallace Hagan Manufacturing Co., Memphis, Tennessee
11:10	DIMENSIONAL SIZE SEPARATIONS (a) Width and Thickness Separations - G. M. Dougherty, Staff (b) Length Separations - C. E. Vaughan, North Carolina State University and Mississippi State University
12:00	LUNCH
1:25	"Thru Better Design" Presiding: Jim Beck
1:30	FUNDAMENTALS OF SEED DRYING - Bowen Campbell, Campbell Industries, Des Moines, Iowa
2:15	EFFICIENT PLANT DESIGN - G. Burns Welch and Panel
3:00	COFFEE, COKES, DOUGHNUTS
3:30	DEMONSTRATIONS OF SELECTED PROCESSING EQUIPMENT - Staff and Manufacturers' Representatives and SEED QUALITY CONTROL METHODS II
7:00	MISSISSIPPI STYLE BAR-B-QUE Courtesy, Sawan Division, W. R. Grace Company, Columbus, Mississippi

Thursday, April 24

8:25	"Thru Treatment and Storage" Presiding: Charles C. Baskin
8:30	SEED STORAGE (a) Biological Considerations - James C. Delouche, Staff (b) Engineering Considerations - Jim Beck, Staff
9:30	SELF-EVALUATION EXAMINATION
9:45	COFFEE, COKES, DOUGHNUTS
10:00	DRAWING FOR DOOR PRIZES
10:15	APPLICATIONS OF COLOR SORTERS IN SEED TECHNOLOGY - A. H. "Bill" Boyd, Jr., Staff
10:45	SEED TREATMENTS AND TREATERS - C. Hunter Andrews, Staff
11:15	SUMMARY OF COURSE
12:00	LUNCH
1:30	Conferences with Program Speakers or Special Demonstrations as Requested

SEED POWER

Charles E. Vaughan[1]

Power is a much used word in our world today. We often hear of military power, economic power, voting power and cleaning power. On the campus at North Carolina State University, I have seen automobile bumper stickers that say "Sigma Pi Power." It seems that everyone is thinking in terms of power. Today, and throughout this week we are going to apply this word to our own profession and talk in terms of "Seed Power."

When one thinks of "Seed Power" no doubt the first thought that comes to mind is a vigorous plant, growing from a seed, recently planted in well-prepared soil. But "Seed Power" can mean much more to one who gives it a second thought.

Even the caveman was aware of "Seed Power." His only tool, the club, had power and gave him dominion over the other animals. However, much of his energy was expended maintaining his dominion and therefore, he had very little time for anything else. Then he discovered seed. And, seed had power - more power than his club. He collected seed, saved them, and planted them in soil at a site of his own choosing. Food supply was almost insured - he multiplied, and some of the group did not have to be food gatherers or raisers - so they developed irrigation systems to water crops, invented the wheel to transport them, and made pots in which to store the grain.

Yes, the discovery of seed and its power was a key element in the development of man and his civilization.

Let us consider several questions. What is a seed? From what is its power derived? How may we utilize this power?

In answering these questions let us consider "Seed Power" from four viewpoints.

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[1] Mr. Vaughan is a Graduate Research Assistant, North Carolina State University and Assistant Professor of Agronomy on leave from Seed Technology Laboratory, Mississippi State University.

SEED POWER THROUGH KNOWLEDGE

There are many factors that interact in the minds of seedsmen which influences the production, processing and marketing of high quality seed. Knowledge leads to power. So, the more we know about seed and of these factors the more power we can derive from them.

Therefore, the first thing we need to know is the answer to the first question that was posed a moment ago, "What is a seed?" Basically, a seed consists of three parts: (1) embryonic axis - consisting of a minature plant inside the seed with a radicle that will develop into the primary root and a plumule that will develop into the stem and leaves above ground; (2) nutritive tissue such as the seed leaves of soybeans and peanuts or the endosperm of corn and sorghum; and (3) a good covering known as the seed coat.

Second, we need to have knowledge of the importance of seed. Over 60 percent of the food consumed by mankind is seed or seed products such as flour, meal, oil, etc. If we stretch the definition of "seeds" to include vegetative reproductive structures such as tubers, then the portion of man's food from "seed" is over 75 percent. Stored in seed are three important nutrients: carbohydrates, fats and oils, and proteins. Americans get much of their proteins from meat, but in many countries of the world the principle source of protein is seed.

Seeds are an aid in efforts to improve plants. Most purposeful plant "improvements" have come about through sexual reproduction and the consequent formation of seeds. Useful variations in hereditary characteristics occur much more often, incidental to sexual propagation, than in asexually propagated plants. Think how difficult it would be if plant breeders could not transmit their work through seed. Surely, it is done with tubers, corms, rhizomes - but it is not easy.

Large progenies generally can be developed rather quickly and inexpensively through the agency of seeds. Large numbers greatly increase the probability of finding truly superior plants for further mating with other desirable parent plants.

The compactness and longevity of most seeds enable the plant breeder to safely store collections of germ plasm in a small space and at very little cost. The miniaturization of the seed also permits it to be carried or naturally disseminated over long periods of time and over great distances. Old Johnny Appleseed could carry a lot of apple seed in a small bag - but he wouldn't have gotten far if he had had to carry seedlings or rooted cuttings. Similarly, the Pilgrims brought over wheat and other seed - but how would they have fared if they had had to bring cuttings or other vegetative materials?

Seeds are the raw materials for making a great diversity of important products for use in industry and for making pharmaceuticals, cosmetics, and alcoholic beverages. Among these various purposes, the oilseeds have the widest range of uses. Millions of tons of both oily and starchy seeds are used every year in this country for products other than food and feed.

Seeds are the protectors as well as the propagators of their kinds. Thousands of kinds of plants have evolved in such ways that they cannot survive, even in the regions where they are best adapted, if they produce no seeds. Seeds of most plants are the very means of survival of the species. They carry the germ plasm, variously protected against heat, cold, drought, and water from one growing season to the next.

The essential role of seed then lies in its generative function- the capacity to reproduce that from which it came - the grain and fibers, the grass and the trees.

Third, we need to have a knowledge of good seed. All seed certification manuals give a good definition of what is meant by improved or high quality seed. Two things are emphasized.

<u>Genetic Purity</u>:

Genetic purity is maintained by following a set of guidelines or regulations which involve planting seed of known genetic identity, and maintaining this identity through proper isolation from other fields, and by field inspections.

High Germination Percentage:

A high germination percentage is an important characteristic of high quality seed. Standards have been set for all crops and should be only a lower limit rather than a goal to achieve. The potential use of seed for planting purposes makes it necessary to have an appreciation of good, high quality seed. The biological characteristics and potential uses of seed, then have given them their power.

Since seeds have power our efforts should be to see that this power is not diluted, that it is preserved, and that its application is facilitated or enhanced. Let us look at some of the ways seed power is diluted. Seed Power is diluted by:

1. Weeds in the field
2. Weed seeds in the crop seed
3. Other varieties in the crop seed
4. Other crops in the crop seed
5. Inert material - trash - splits

In addition to being diluted, seed power can also be lost. Seed power is lost by:

1. Low germination
2. Poor stands in the field
3. Seed power is also lost during production in the field.

Therefore, we need to have a knowledge of production requirements. Over the years general practices for the field production of seed have evolved. These are highly developed but generally known by most seed producers. However, there are some important points worthy of mentioning here today.

A knowledge of how weather conditions affect the viability and vigor of the seed produced is of particular importance.

A seed crop attains its highest quality at the time of full maturity. When the seed reaches maximum dry weight the principal process thereafter is loss of moisture. From this point of full maturity, the vigor of the seed crop can only decline, and our objective should be to slow this decline as much as possible. The extent of our success will determine the quality of our product.

Moisture content of the seed from the time of full maturity must receive primary attention, and the practices followed should be directed toward lowering the moisture content to a level where decline of vigor is minimized. Harvest at full maturity is impractical for most crops because of the high moisture content, although some, such as corn, can be harvested essentially at this stage and artificially dried.

Since most crops must dry down to safe harvesting moisture in the field so that harvesting machinery will not damage the seed, weather conditions in the area of production are important in determining decline in quality while the seed are still in the field. Excessive humidity during the period from full maturity to harvest is especially damaging and, in some cases, can result in complete deterioration before the seed can even be harvested. Because of this, production areas should be chosen where favorable weather conditions may be anticipated prior to and during the harvest period.

A knowledge of the role of mechanical damage in contributing to seed deterioration is also important. In their long journey from seed head to seed bed, seed are subjected to many physical and mechanical processes which cause the seed to lose their power. Many of these processes or operations can and do cause injury. The results are cracked, chipped, scraped, cut, broken or internally damaged seed. We would not be too alarmed about mechanical damage if only the physical appearance of the seed was affected. The consequences and effects of mechanical damage, however, are much more serious.

Mechanically damaged seed are:

1. More difficult to clean
2. Lost in clean-out
3. Lower in germination
4. Reduced in vigor
5. Lower in storage potential
6. More susceptible to chemical treatment injury
7. More susceptible to destructive soil organisms

There are other factors - some recently discovered - which contribute to "Seed Power" through knowledge.

H. B. Harris and M. B. Parker of the University of Georgia have discovered and recently reported that the seed source affects yield of soybeans. In other words, the progeny of seed of the same soybean variety grown at various locations do not possess the same yielding potential. They have reported that the yield difference between plants grown from seed from different locations but of the same variety was as much as 510 pounds (8 1/2 bu.) per acre.

Mr. Nirmal Gill, who has just recently completed the requirements for the Ph.D. degree here at Mississippi State University, has reported that subtantially reduced yields of corn were produced by deteriorated seed. This is a very significant finding and should give impetus to efforts to establish an effective vigor test that can be applied to all seed.

Another factor that contributes to "Seed Power through Knowledge" is a knowledge of our own contributions to the seed industry. The March 1969 issue of Crops and Soils reports that the Michigan certified seed growers have produced an attractive, precautionary sign which also advertises merits of their certified seed fields. These signs serve a very useful purpose in certified seed fields especially where very contagious diseases are continual problems. Such diseases can be spread merely by walking through the fields, and persons are discouraged from entering fields except when absolutely necessary.

The signs also affect how clean and attractive individual seed growers keep their fields. If a grower sets his sign in a field, he usually takes better care of the field's appearance than he otherwise would. The point I want to make here is that our awareness of being on public display will help us to improve on our performance.

SEED POWER THROUGH PLANNING BASED ON KNOWLEDGE

This point can be condensed into one idea. We should plan for a reduction in the rate of seed deterioration, for deterioration means a loss of seed power.

Seed deterioration is the net total of all physical, physiological, biochemical and chemical changes occurring in a seed which ultimately leads to its death.

We cannot prevent deterioration; we can, however, influence or control its rate. One way in which we can plan for a reduction in the rate of seed deterioration is to plan for harvest at the right time. Conditions in the field during seed development and maturation have an important influence on the subsequent characteristics of the seed: prevalence and persistence of hard seededness and dormancy, extent of mechanical damage, viability, vigor, test weight, appearance, and storability. Adverse field conditions are well known: early frost damages corn, peanuts and sorghum; dry-hot weather leads to a rapid loss in seed moisture, small seed size, low test weight and more mechanical damage during harvest; warm-humid weather is conducive to weathering and deterioration in soybeans, cottonseed and sorghum. We should plan our harvest so that a minimum of deterioration occurs before harvest.

One can plan for and control such things as mechanical damage which predispose seeds to rapid deterioration. In planning for a reduction in mechanical damage, several points must be considered.

Let us look first at the harvesting operation. The speed of the threshing cylinder chiefly determines the force of the impact of the machinery with the seed. Since high speeds damage the seed and low speeds may not thresh completely, the operator is in somewhat of a dilemma when it comes to adjusting cylinder speed.

As a rule of thumb, speed of the cylinder should not be any faster than required to thresh the seed. It should be remembered that the speed required for threshing in mid-day will probably be less than during early morning and late afternoon. Close attention at this point will minimize seed injury considerably. In shelling corn, the sharp edges of sheller bars or teeth can be filed off and speed reduced 1/3 to 1/2 from that used in commercial shelling to decrease pericarp injury.

We should plan for a reduction in the rate of seed deterioration by planning for a reduction in impact injuries. Various devices can be installed for reducing the impact of seed falling into deep bins or into equipment hoppers. Little can be done to decrease mechanical injury in the cleaning and sizing equipment but speed and adjustments of debearders and scarifiers must be carefully controlled if impariment of seed quality is to be kept at a minimum.

We should plan for a reduction in the rate of seed deterioration by planning for proper drying and storage of our seeds.

Most of us are aware of the influence of storage environment on retention of viability and vigor. Several years ago we received a rather irate letter from a seedsman. This seedsman had read one of our articles on seed storage in which it was stated that seed retained their viability for a long time in "cold storage." He had a 2,000 bu. carry-over of some certified seed of wheat, and had placed them in "cold storage" after the planting season. The seeds remained in cold storage for 8 months and were removed from storage in August. Samples tested 6 weeks after the seeds were removed from storage showed only 32% germination. (The seeds at the time they were placed in storage germinated above 90%). The seedsman wanted to know why we had recommended "cold storage" when it was so obviously detrimental to the seeds. Upon investigation, it was determined that the seed were stored in the type of cold storage facility used for vegetables and other succulent materials. The temperature was about 40°F. and the humidity near 100%. Under such conditions the moisture content of the wheat had increased to about 18%. When the seeds were taken out of storage in August the temperature was near 100°F. At this combination of high moisture content and temperature, it didn't take long for the seeds to deteriorate to 32% germination. The seedsman finally admitted that the article referring to the beneficial effects of low temperature <u>also</u> stated that <u>low</u> humidity was essential.

We should also plan for proper packaging. There is currently much interest in packaging, particularly in the use of plastic bags. The idea is to place a moisture vapor proof barrier between the seed and the environment so that the moisture content is maintained at the same level as at the time of packaging. This is a good development. However, several precautions must be observed. Generally, seed moisture contents for sealed storage should be 2 to 3% lower than that considered "safe" for unsealed storage. And the vapor barrier should be maintained. I am reminded here of a contact with the packaging division of a large manufacturer. They were working with a corn producer on the use of plastic bags. Corn was dried to 10%, sealed in 6 mil-polyethylene bags and placed in a "tropical" room for observation. After 6 months under warm humid conditions in the tropical room - the corn seeds were always dead. We puzzled over this awhile and finally learned that thousands of tiny holes were punched in the plastic bags before packaging because everyone was afraid that otherwise the seed might smother: after all, they were alive. The seed, of course, might just as well have been in a cloth bag as in a perforated plastic bag. Seeds don't smother, they do respire, but very little. Vegetable seeds have been packed in air-tight, vapor-tight cans for years.

SEED POWER THROUGH ACTION BASED ON SOUND PLANNING

The most successful programs in any organization are action-programs. Briefly, here, I want to talk about three areas in which we would do well to concentrate some action. To do so will improve the quality of the seed we plant and the quality of the seed we produce.

Vigor-testing of seed:

Over the years numerous attempts have been made to establish a vigor test that will be universally accepted. Some of these tests are as follows: The cold test, length of primary root, GADA (glutamic acid decarboxylase activity), the tetrazolium test, changes in permeability, respiration rate, the brick gravel method, and microscopic examination for mechanical damage.

Most of the tests that have been proposed do a reasonably good job of detecting differences in quality among seed lots. However, of all tests , the tetrazolium test is perhaps the best known and most widely used.

For the past two years I have worked in North Carolina, a state that has made wide usage of the tetrazolium test. This is due largely to the efforts of Dr. R. P. Moore. I have seen the advantages of using, on a regular basis, an acceptable vigor test. Last year more than 2,000 samples were submitted for testing with tetrazolium. Reports on each of these samples were in the mail within 24 hours after being received. In addition to a report on the potential germination, a vigor rating for each sample was listed on the report. This is valuable information and is provided in a relatively short time. It is still not recognized as an official test, but provides information for making quick decisions on many seed lots - both for the seedsman and the farmer.

Other states would do well to follow the lead of North Carolina. Most people there who use this service have come to rely on the information it can provide. This type of service can enhance the seed power for those who make use of it.

Predicting Seed Storability:

Two of the most important quality problems which a seedsman faces today are seed storage and seed vigor. During the course of routine operations, a seedsman normally handles many different lots of the same kind and variety of seed. Judgements as to the relative quality of these seed lots are based primarily on the results of standard purity and germination tests.

The seedsman, however, faces several situations in which the information normally available to him concerning seed quality does not provide a suitable basis for making a decision. One such situation is a determination of which lots should be marketed first and which lots should be held for possible carry-over if the market is not strong, or as a hedge against shortage the next year. Germination percentages of the lots provide some useful information for making this decision if there is a considerable range in germination among the lots. However, germination percentages among various lots are often quite similar. Hence, a seedsman is reduced to a more or less random selection of lots for possible carry-over. He often finds the next season that several of the lots have drastically declined in germination . Such experiences involving seed lots of the same kind, variety, chronological age, and germination that do not maintain viability equally well under similar storage conditions are common to all of us. The failure of a seed lot of apparent good germination to maintain that germination in storage at a retail outlet, or at the wholesaler, constitutes a serious problem. This can be damaging to a seedsman's reputation.

It is apparent that some important aspects of seed quality are not reflected with any consistency in the information provided by standard seed tests. A high germination percentage does not necessarily mean that a seed lot will store well or that it will produce a satisfactory stand even under relatively favorable conditions.

The solution to the problem of storability lies in the development of a test - other than the standard germination test - which will differentiate among seed lots with respect to storage potential and field emergence capability. Such a test has been developed by the Seed Technology Laboratory - the "accelerated aging test."

We need to make use of this test or a similar test, to evaluate seed lots for carry-over purposes. A test such as this might eliminate the need for diversion of large volumes of seed into other channels or being destroyed because it is worthless. Certainly here seed power can be enhanced.

Setting-up of quality control programs:

Those who are engaged in the production of seed can improve their "seed power" by setting up a quality control program.

Dr. C. D. Harrington of Asgrow Seed Company outlined a plan for a quality control program in the 1967 Proceedings of the Short Course for Seedsmen. According to Dr. Harrington, "the first step an organization must take to get the ball rolling is an administrative decision to improve its quality control program and to provide a policy outline of its purpose and scope. These depend in large part upon the type of organization involved. For example, if a state or federal department is engaged in the production of seed of the best possible quality for use as breeder stock, then high processing standards may simply be set to obtain this quality level. On the other hand, if a commercial seed house is engaged in the production of seed, the company objective would be to set its quality standards at a level which will permit it to produce a uniformly high standard of seed quality at a reasonable profit. And this is quite an undertaking."

"A progressive organization which decides to set up a formal quality control program does not really start from scratch. Usually, it already has an active program of some sort involving a number of people. These include those who sample crops in the warehouse. Those who make decisions on processing procedures, those who check the processed product for market suitability, and those who buy and sell the seed during the normal course of operation."

"The best place to start, therefore, would be to review and standardize those quality procedures already in use. This should include the reorientation of individuals involved to the necessity for unvaried compliance in carrying out these procedures. The first effort toward improving a company's quality control effort should be sound management procedure. This demonstrates to personnel already involved how to do a better job with familiar routines."

"After improving on the familiar routines, the position will be reached where new procedures will be readily accepted. A satisfactory vehicle for this step would be a small manual designed and written for a two-fold purpose: (1) to improve the technical knowledge of the personnel involved, and (2) to introduce more reliable equipment and procedures than those presently being used."

What benefits can the seedsman expect to derive from producing, processing and selling high quality seeds? As everyone knows the seedsman's reputation is his most valued asset. His business is founded upon his good name. It is true that some profits can be made from "one-time" customers, however, the reputable seedsman wants more than one sale per customer. Repeat business is needed in order for the seedsman to operate on a sound basis. His reputation is based upon the quality of seed he sells.

High quality seed can be expected to demand a premium price. The consumer will get more for his money - even at a higher price per unit - with high quality seeds than with those of lower quality. Also, the fact that high quality material is handled can be used to good advantage in advertising and promotional campaigns.

Dealing in high quality seeds will tend to help alleviate customer complaints and adjustments to the seedsman due to seed failures when planted. High quality seed will perform better under field conditions than will those of lower quality. This will further enhance the seedsman's reputation.

I think that you will agree with me that the seedsman can afford to produce and sell nothing but the highest quality seed possible.

SEED POWER THROUGH TOTAL COMMITTMENT TO HIGH QUALITY STANDARDS

A seed is at its maximum viability and vigor at the moment it reaches full physiological maturity in the field. The various steps which it undergoes in harvesting, processing and storage cannot improve it - it can only go down in viability and vigor. How much the viability and vigor is decreased depends upon the extent of our committment to maintain high quality standards.

One of the first things to which we should be committed is the improvement of seed quality by the improvement of growing conditions. This will improve on the maximum level of viability and vigor attainable in the field. The closer we can come to perfect growing conditions, the better the seed will be. Growing conditions can be improved by the use of proper fertility practices, insect and disease control, and irrigation. In some cases it may be necessary to change growing areas. This has been true in the bean and pea seed industry. Formerly, beans and peas were produced in the Eastern and Mid-Western areas of the United States. It was found, however, that in the western areas of the country, high quality seed could be produced due to less humid and more disease and insect free conditions.

Much can be done to preserve seed quality in the way the seeds are harvested, processed and handled. Improper harvesting and processing can contribute greatly to deterioration. Mechanical damage probably cannot be completely prevented. It can, however, be minimized. Seedsmen who have mechanical damage problems should carefully analyze each operation from harvest to bagging to determine the major causes of damage. After the major causes of mechanical damage are identified, the appropriate actions necessary to alleviate the condition can be planned and implemented.

High quality seed can be ruined by improper storage. You have all had experience with, or heard of serious damage occurring to seeds during storage. Care must be taken to insure that the conditions under which the seeds are placed are such that no serious deterioration in quality will take place. A good rule of thumb to use is that the temperature in degrees Farenheit plus percent relative humidity in the storage atmosphere should equal 100 or less for good storage conditions. When packaging seed in moisture proof or moisture resistant packages one should be very careful to insure that the seed moisture content is at a level low enough to be safe for sealed storage. Serious damage can occur to the seed if the moisture content is too high.

Another factor to be considered in seed quality is the appearance of the seed. It is true that appearance may not affect the performance of the seed when planted, nevertheless, the buyer is going to be influenced by how the seed looks when he makes his purchase. Discolored seed will not be purchased as readily as bright, well colored seed. In the improvement of appearance, one must consider such operations as polishing, debearding, hulling and even dyeing the seed a desirable color.

Another area in which we must be committed to high quality standards is in the area of "Seed Processing".

New and improved crop varieties become an important agricultural input only when seed of such varieties are available to farmers varietally pure, in a viable condition, free of contaminating weed seed and in adequate quantities at the right place and time. Seed processing is an integral part of the technology involved in transforming the genetic engineering of the plant breeder and geneticist into improved seed. In its broadest sense, seed processing encompasses all the steps involved in the preparation of harvested seed for marketing - handling, shelling, preconditioning, drying, cleaning, size-grading, upgrading, treating and packaging. In common use, however, the term seed processing refers only to the preconditioning, cleaning, size grading and upgrading of seed.

Seed growers and producers are dependent on the seed processor for preparation of their seed for market. The quality of the final product, regardless of its inherent capacity to produce, is directly related to the processor's ability to: remove contaminants and low quality seed, to properly size-grade for precision planting, to treat the seed effectively, and to prevent mechanical mixtures of the seed with those of other varieties or hybrids. In turn, the processor's ability to render these services efficiently and effectively, is greatly affected by the types of processing and handling equipment available to him, their arrangement within the plant, his skill in operating them, and his knowledge of seed characteristics and how they relate to processing.

Think of seed processing and you think of equipment and machinery, conveyors and structures. For it is hard to believe that quality seed of improved varieties and hybrids could be made available in the quantities required by farmers without a high degree of mechanication of the many steps involved in the processing and preparation of seed. Thus, seed processing involves more mechanical skills and engineering principles than are involved in other areas of seed technology.

A variety of contaminants must be removed from raw seed - particularly seed harvested by a combine - to make it ready for marketing and planting. Contaminants such as inert material and off-size seed are not, in themselves, harmful but they do greatly influence seed flowability and plantability, incidence of insect infestations, and contribute to storage problems. Other contaminants such as weed seed and seed of other crops and varieties can seriously affect production of crops if they are not removed.

Seeds are processed to remove contaminants, to size-grade for plantability, to upgrade quality through removel of damaged or deteriorated seed, and to apply seed treatment materials. The demands of the seed producer and seed consumer require that these four objectives be achieved effectively, efficiently and with minimal damage to the seed.

A variety of equipment is available for processing seed. It ranges from the simple winnowing tray - still used in many areas of the world - to complex and highly sophisticated equipment such as the electric sorting machine. Although variable in type and design, all seed processing equipment have one thing in common: the separations they effect are based on differences in physical properties among desirable material (good seed) and undesirable material (contaminants). Some machines separate good seed from contaminants on the basis of differences in several physical properties. More often, however, satisfactory removal of contaminating material from seed required that they be processed in a specific sequence through several machines with each machine removing a certain portion of the contaminating material.

The choice of a machine or sequence of machines for processing seed depends on the kind of seed being processed, the nature and kinds of contaminants (weed seed, other crop seed, inert matter, etc.), the quantity of each in the raw seed, and the quality standards that must be met. Thus, the processor must be as familiar with seed standards and seed characteristics as he is with processing equipment.

Yes, seed processing is one of the best ways to enhance the "Seed Power" already available to us. Because of this we will devote a lot of time this week to seed processing. This is made possible because of our unique facility - the Mississippi Seed Technology Laboratory - with its collection of the latest in seed processing equipment. However, this does not mean that other important areas of seed improvement will be excluded.

All of us are perhaps familiar with the words from the Bible, "Whatsoever a man soweth that shall he also reap." So why shouldn't we sow seeds with power and reap the profits that can be ours.

FUNDAMENTALS OF SEED PROCESSING[1]

A. H. Boyd[2]

Millions of years ago the first men to roam our earth had no need for a knowledge of agriculture. He was few in number and had vast areas of unspoiled territory in which to roam and gather his food. He had probably discovered that he could eat parts of some plants when meat was scarce. The most significatn disvoery of the ages was when one of these early humans noticed that the seed from his favorite food plants could be dropped in the soil and he could come back later and find the same kind of plant growing more food. This allowed him to establish permanent settlements and support an ever increasing population. Now over half the people who have ever lived on our globe are alive today! Our seacoasts are teeming with ships and our cities are busy attending to the business of our internal and world wide commerce.

Where do we as seedsmen fit into this picture of ever-increasing population? Millions of people get hungry three times a day. Those are the lucky ones. Many are always hungry. To supply the huge amounts of food and fiber for our people, our fields are a far cry from the small food patches of the early farmers. Grin moves to market through modern high speed grain elevators to be stored and shipped as needed. Other commodities are moved through equally efficient channels. To supply a basic ingredient, seed, for such a system, it is our charge to supply high quality seed of the needed kinds and varieties in sufficient quantities at a reasonable price. To do this we must not only have good efficient equipment. We must know how to operate it.

Let us now pull our chairs up around the conference table and discuss some of the fundamentals of seed processing. First, let's identify the basic problems in operating a processing plant.

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[1] Mississippi Agriculture Experiment Station Journal No. 1624. Prepared for Seedsmen's Short Course, University of Georgia, Athens, Georgia.

[2] Mr. Boyd is Assistant Agronomist and Foundation Seed Manager, Seed Technology Laboratory, State College, Mississippi.

1. The most complete cleaning job that is practical.
2. Mixture prevention through good design and careful operation.
3. Good records for complete identity.
4. Use of these records for evaluation and improvement.

Since time is limited we will spend most of our time on the principles and machines used to attack the first part of the problem.

PHYSICAL PROPERTIES OF SEED

To successfully clean a lot of seed we must analyze the sample to see what physical characteristics of the seed and/or other materials present can be used to accomplish a separation. Next we must know which machine will do that job and how much to expect from it.

Size:

The first physical characteristic to think about is size. The air-screen machine and the width and thickness graders such as the precision grader and the Rock-it separate according to size.

The air-screen machine is the basic and often the only machine used in seed cleaning. A modern air-screen machine shown on the slide has two air systems and five screens. The top air will be used to lift the very light chaff and dust as the seed flow from the feed hopper. The top screen is called the top scalper and is usually a large round hold screen to remove only the large trash and long stems. The seeds drop through to the first grading screen which has the smallest openings of any of the screens used and drops only the small seed out. The seeds going over the first grading screen are fed onto the second scalping screen which has smaller openings than the first scalper and removes anything which is slightly larger than the good seed. The material which drops through the second scalper goes to the second grading screen which has slightly larger openings than the first grading screen and removes seeds which are smaller than the good seeds. Next the third grading screen has openings only slightly smaller than the good seed and is the final screen before the good seed pass across the bottom air which is set to remove lighter immature seed and light particles of foreign material which may still be present.

Some things which may help you operate your air-screen machine more efficiently are:

1. Attaching an oil cloth, slick side down, so that it holds long seed or straw flat on a top screen preventing them from turning on end and falling through with short seeds.

2. Placing strips of wood or sash cord across screens to form screen dams to hold seed on a screen longer and allow a better chance for a more complete separation.

3. Installation of clay crushing rolls to break up pieces of clay but not damage seed so that screens and air can remove the soil.

4. Using the tilt of the shoe to control the rate of movement of seed through the machine. The rate of vibration should only be adjusted to keep the material "live" on the screens.

After basic cleaning the precision grader can be used for some very close separations of contaminants and for width and thickness grading of corn. The precision grader uses a rotating shell and baffles to tumble the seed so that they will present the proper sides for grading.

Length:

The air-screen machine is not capable of all separations necessary in seed processing. Where it fails we must go on to other, more specialized machines. The next property is length. The indent cylinder and the disc separator separate seeds by length.

Here is an example of peas, vetch, and oats. You will notice that all the seeds are the same width but the oats are, of course, much longer. The pockets on the face of a disc are cut out so that a short seed can sit in the pocket and be lifted out of the mass of seeds, but a longer seed will overbalance and fall back into the mass. To gain capacity many discs are mounted on one shaft. The mass of of seeds is fed into one end of the machine and small paddles on the hub of each disc propel the seed toward the other end. As the seed are flowing through the machine the discs have the opportunity to lift out the short materials. Discs are made in many sizes for specific separations.

The cylinder separator is a length separator which uses centrifugal force and indents on the inside of the cylinder to accomplish a separation. Seed is fed into one end of a revolving cylinder until a bed of seed is built up. The rotation of the cylinder tumbles the seed bed giving all the seeds an opportunity to fit into one of the indents. Shorter seeds are held in the indents longer as the cylinder rotates and an adjustable trough catches the highest lifted seeds and conveys them down the center of the machine. By varying speed of rotation, position of the leading edge of the trough and varying the indent (by changing the cylinder) an excellent job of length grading is possible. It should be pointed out here that the cylinder does its best on materials having a weight per bushel of 45 pounds or over. On light and chaffy seed the disc should be chosen.

Shape:

Many things are recognized by their shape. To separate seed by differences in shape we use a spiral separator or draper. The length graders and air-screen machine also separate by shape to some extent. Consider this illustration of soybeans and giant morning glory seed or moon flower. The soybeans are almost spherical while the moon flower seeds have two flat sides much like the sections of an orange. If these seed are allowed to roll down an inclined plane the soybeans will gain much more speed. If the plane is curved the faster seed will move to the outside of the curve. This is the basis for the spiral separator. The faster moving seed jump off the inner spiral into an outer spiral and the slower seed remain on the inner spiral and slide down into a separate chute.

The draper belt takes advantage of these same characteristics. It consists of an inclined canvas or plastic belt which moves up hill. The round or smooth seed roll off the bottom and the flat or rough seed are carried over the top.

Weight:

It is easy to classify many things by weight. Seed too, are often separated on the basis of weight or specific gravity. To do this we can use the pneumatic separator, aspirator, gravity table, or stoner.

Here is an example of wheat with insect damaged seeds. This would be obvious separation by weight. One way to do this is with the pneumatic separator. The pneumatic separator consists of a fan blowing a column of air through a tube. The seed are fed through a chute across this column of air where the lighter "rejects" are blown upward into a collector cone and the heavier material flows across into its chute.

The aspirator also uses air for its separation but it operates on vacuum rather than pressure. This is the basic difference between an aspirator and a pneumatic separator.

The gravity table is one of the most useful and misused machines in our processing plants. Gravity tables make separations by weight or specific gravity through use of a tilted oscillating deck with a perforated cover. This deck varies in degree of roughness and size of perforations depending on the size and kind of seed to be separated. Deck materials range from cloth for clovers to rough screen wire for corn and cotton seed. Fans furnish a positive air pressure in an air chest beneath this deck. By adjusting the air pressure seed fed onto the deck are lifted slightly so that the lighter seed do not sit as firmly on the deck as do the heavier seed. The pitching motion of the deck then tends to kick the heavier seed uphill on the deck with each upward stroke.

The stratification of the varying weights caused by the lifting effect of the air and the action of deck allows the lighter seed to tumble to the low side of the deck. End tilt causes the separated seed to work their way off the lower end of the deck as seed are fed onto the upper end. The separation needed is selected by the divider location at the end of the deck.

Some of the common mistakes gravity table operators make are:

1. Machine installed on a weak foundation.
2. Blowers running backwards.
3. Operating with excess air.
4. Operating with insufficient air.
5. Attempting to separate materials not suitable for gravity separation.
6. Using the wrong deck.
7. Trying for capacity before obtaining an efficient separation.
8. Air not clean.
9. Belts slipping.
10. Covers over air filters not removed.
11. Irregular feed.

The gravity can be expected to:

1. Separate materials of the same size but differing in specific gravity.
2. Separate materials of the same specific gravity but varying in size.

The gravity table will not separate materials varying in size and specific gravity. An example of this would be wheat and oats. In such a case you would get a small fraction of heavy wheat, a small fraction of light oats and a large meddling product consisting of essentially what you started with.

A variation of a gravity table is the stoner. It was developed, as the name suggests,to remove stones from seed. It gives more capacity for the horsepower and dollar expended but has the disadvantage of making only a "yes or no" separation.

<u>Surface texture</u>:

Another physical characteristic we can exploit to make separations is the surface texture of the seed. The roll mill is the most used machine in this category. It consists of contrarotating velvet covered rolls. The seed to be separated are fed onto one end of the rolls, and as they work their way down between the rolls the nap of the velvet catches the rougher seed and tosses them over the side. The smoother seed are relatively unaffected and continue on down the rolls and are fed into a chute at the end. An adjustable curved shield is located over the rolls so that rough seed tossed into the air can be deflected over the side. Adjustments of the roll mill include: speed of rotation of the rolls, tilt of the machine and clearance of the shield.

The draper separates on seed coat texture in the same manner as it does for shape.

Color:

Color is a character which is increasingly used in seed processing. The electric color sorter does this job for us.

This basic unit of the electric color sorter is the photoelectric cell which changes its electrical characteristics in proportion to the light which strikes it. By positioning light filters in front of the photoelectric cells they can be made sensitive to color as well as brightness. One type of electric color sorter feeds the seed from a vibrator to a U-shaped belt which conveys them off the end of the belt where they fall free through the optic box. Here they are scanned, classified, and if rejected a jet of compressed air kicks the rejected seed into a separate chute. If they are accepted they are allowed to continue on their trajectory into an "accept" chute. Another type does essentially the same job but to gain capacity and precision the seed are fed into a spinning bowl where they are picked up on the ferrules of a drum by vacuum and conveyed through the optic box for scanning and classification. An air ejector is mounted inside the drum to reject any of the seed which are graded as "reject" by the machine. Even though the color sorters are comparatively expensive they are extremely versatile and seedsmen are finding increasing uses for them.

Affinity for Liquids:

Some seeds have a greater affinity for liquids than others. The magnetic separator and buckhorn machine use this principle for their separations. The magnetic separator consists basically of a seed feeder, water spray, iron powder supply, mixing chamber and a magnetized drum. The seed with a greater affinity for water become wet and sticky and therefore, adhere to the iron filings. Then as the seed flow over the magnetized drum, the magnets attract the iron filings causing the seed to be held close to the drum and fall behind a divider while seed with no filings attached drop off readily into the main flow.

The buckhorn machine works on the same principle except that fine sawdust instead of iron filings is fed into the mixing chamber. This machine was developed to remove buckhorn plantain from clovers. The seed of buckhorn plantain become sticky when moistened and adhere to the sawdust. The mass of seed is then cleaned on an air screen machine. In effect you have changed the size of the buckhorn seed so that it may be separated by another machine.

Conducitivty:

The conductivity of seed vary and the electrostatic separator uses this principle. This machine was developed for the mining industry to process low grade ore and adapted for some uses in the seed and milling industries. It uses a highly charged electrode and a grounded roller. The seed which readily conduct electricity are relatively unaffected and drop off the roll while some of the seed hold the charge placed on them by the field and are "pinned" to the roller and carried under the roll. This machine has much potential but due to its sensitivity to relative humidity and other factors it is not often used in seed processing.

SUMMARY

In summary let us then say seed can be separated on the basis of their:

1. Size
2. Length
3. Shape
4. Weight
5. Surface texture
6. Color
7. Affinity for liquids
8. Conductivity

Now we come to two of the most important tools available to the processing plant operator. They are the scoop and the broom. No matter how good your processing plant is, if you don't keep it clean you cannot expect to prevent mixtures.

When you sell a bag of seed you should be able to tell your customer with confidence that you know what is in your bag. To do this a good set of records is necessary. Your records should give you complete identification of a lot and include information on receiving, drying, processing, packaging, testing, storage, inventory, and sales.

Processing Soybeans for Better Quality

George M. Dougherty[1/]

Processing soybeans for better quality requires that the processor recognize that a completely equipped processing facility can, at best, only imporve the quality of a seed-lot that is received for processing. The heights to which seed quality can be improved through processing is dependent on several factors, among which are: the processing equipment available, and how it is used; and perhaps of even greater importance the quality of the seed as it is received for processing.

High quality seed, that is seed characterized as being vigorous, viable, genetically and mechanically pure, and uniform in attractiveness, is not solely the product of a processing plant; it receives its start in life in the seed field. High quality production control standards do, therefore, become an essential ingredient in the processing of quality seed; these standards must necessarily be higher than those considered average for the industry. The standards adopted must take into consideration the capabilities of the processors processing operation.

Processing soybeans for high quality seed is not particularly difficult provided the crop has met relatively high minimum field standards, and provided pre-processing handling practices have been such as to

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1/ Mr. Dougherty is Assistant Agronomist, Seed Technology Laboratory, Mississippi State University.

prevent the occurrence of contamination or excessive mechanical injury. Generally, good, uniform, quality seed-lot of soybeans can be processed into a high quality product using only an air-screen cleaner and spiral separators, provided the limitations of each of these machines is not exceeded.

The initial, or basic, cleaning or processing operation is performed on the air-screen cleaner. Air-screen cleaners are not all alike, and each has its own limitations. Selection of a cleaner should not be based solely on its cleaning capacity. In selecting a cleaner the processor's primary concern should be in determining the machines performance capabilities and its limitations. For example, a cleaner equipped with a single air system has built-in limitations not usually found in cleaners equipped with two air systems. Likewise, a 2-screen cleaner has limitations not encountered in a conventional 4-screen seed cleaner. For the processing of high quality soybeans it is almost necessary that cleaners have two air systems and be of the conventional 3-or 4-screen type. The "cleaned" seed product from the air-screen cleaner should be a saleable product. It will generally, however, lack the uniformity in appearance associated with high quality seed.

Enhancement of the appearance of the beans is accomplished on spiral separators. These machines will separate the non-spherical shaped particles from the spherical shaped soybeans, thus producing a product any seedsman can sell with pride. Spiral separators are easy to operate and relatively inexpensive, but they are low capacity machines. For the cleaning of high quality beans capacities of a single 2-spiral unit range between 25 and 35 bushels per hour. To obtain greater capacities, additional machines are required. A very effective and efficient arrangement of spiral separators in a soybean processing plant is shown in figure 1. The multiple units pictured, are arranged, side by side, in two "banks" or rows. The two rows are separated by a walk-way which provides the operator access to each unit.

Figure 1. Spiral Separator installation in a Wilson, Arkansas, Soybean Processing Plant.

SEED SEPARATION PRINCIPLES

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P = PRIMARY APPLICATION, SEPARATION OR RESULT
S = SECONDARY APPLICATION, SEPARATION OR RESULT

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MACHINES	APPLICATIONS: ROUGH CLEAN	APPLICATIONS: CLOSE CLEAN	APPLICATIONS: FINAL CLEAN	APPLICATIONS: CLOSE GRADE	SEPARATIONS BY	SEPARATIONS BASED ON: GROSS SIZE	WIDTH – ROUND HOLE	THICKNESS – SLOT HOLE	LENGTH	SHAPE	COAT CHARACTER	RESILIENCE	COLOR	SPECIFIC GRAVITY	TERMINAL VELOCITY	DIELECTRIC CONSTANT	CHARACTER CHANGE: BY REMOVING	CHARACTER CHANGE: BY ADDING	SEPARATION RESULTS: INCREASED PURITY	INCREASED GERMINATION	MORE UNIFORM SIZE	COMMENTS
SCALPER	P				SHAKING OR ROTATING (REEL) SCREEN(S), SOMETIMES WITH ASPIRATION	P													P			INCREASES CAPACITY OF FOLLOWING MACHINES, BUT DOES LIMITED CLEANING JOB, GOOD CAPACITY
ASPIRATOR	P	P			AIR FLOTATION BASED ON TERMINAL VELOCITY	S				S	P			P	P				P	P		INCREASES CAPACITY OF FOLLOWING MACHINES, LARGE CAPACITY ON ROUGH CLEANING, LOW CAPACITY ON CLOSE CLEANING
PNEUMATIC SEPARATOR	P	P			AIR FLOTATION BASED ON TERMINAL VELOCITY	S				S	P			P	P				P	P		DUSTIER THAN ASPIRATOR, OTHERWISE THE SAME
SCREEN, AIR MACHINE	S	P	P	S	ASPIRATION & SHAKING OR ROTATING (REEL) SCREEN(S)	S	P	P		S	S				S		AWNS, HULLS, BEARDS	WATER SAWDUST	P	P	S	BASIC SEED CLEANING MACHINE, BUT SOME SEPARATIONS NOT POSSIBLE
SCREEN GRADER			S	P	SHAKING OR ROTATING (REEL) SCREEN		P	P		S									S	P	P	CLOSE SIZING BY WIDTH & THICKNESS, SHAPE SEPARATIONS DEPEND ON THIS
DISC SEPARATOR			P	P	ROTATING INDENTED DISCS				P										P	S	P	LENGTH SEPARATIONS ONLY, LOW CAPACITY
INDENT CYLINDER			P	P	ROTATING INDENTED CYLINDER				P										P	S	P	LENGTH SEPARATIONS ONLY, FAIR CAPACITY
ROLL SEPARATOR			P		PAIRS OF COUNTER-ROTATING, FABRIC COVERED ROLLS					S	P								P			SPECIALIZED APPLICATIONS, LOW CAPACITY
BELT (DRAPER) SEPARATOR			P		INCLINED, MOVING FABRIC BELT, SOMETIMES CANTED, SOMETIMES VIBRATED					P	S								P	S		SPECIALIZED APPLICATIONS, LOW CAPACITY
GRAVITY TABLE			P	S	AIR FLOTATION BASED ON SPECIFIC GRAVITY AND, OR TERMINAL VELOCITY	S				S	S			P	P			WATER, SAWDUST	P	P	S	SPECIALIZED APPLICATIONS, REASONABLE SKILL & PROPER INSTALLATION REQUIRED, REASONABLE CAPACITY
STONER			P		AIR FLOTATION BASED ON SPECIFIC GRAVITY AND, OR TERMINAL VELOCITY	S				S	S			P	P				P	S		SPECIALIZED APPLICATIONS, SENSATIVE TO FEED, REASONABLE SKILL & PROPER INSTALLATION REQUIRED, GOOD CAPACITY
BUMPER MILL			P		INCLINED & CANTED, BUMPING, SOLID, TEXTURED DECK					P	P			S					P			VERY SPECIALIZED APPLICATIONS, VERY LOW CAPACITY
VIBRATING TEXTURED DECK			P		INCLINED & CANTED, VIBRATING, SOLID, TEXTURED DECK					P	P			S					P			SPECIALIZED APPLICATIONS, LOW CAPACITY
SPIRAL GRAVITY SEPARATOR			P		INCLINED, SPIRALED SURFACE					P	S			P					P	S		SPECIALIZED APPLICATIONS, LOW CAPACITY
HORIZONTAL DISC SEPARATOR			P		ROTATING HORIZONTAL DISCS & STATIONARY PLOWS					P	P			S					P	S		MORE FLEXIBLE & MORE CAPACITY THAN SPIRAL GRAVITY SEPARATOR
NEEDLE SCREEN			P		FREELY VIBRATING, SPACED FINGERS (GRIZZLEY)	S		P											P	S	P	SCREENS ARE SELF-CLEANING; GOOD CAPACITY
PHOTO SEPARATOR			P		PHOTO-ELECTRIC CELL								P						P	S		HIGH FIRST COST, HIGH SKILL REQUIRED, LIMITED TO COLOR SEPARATIONS ONLY, LOW CAPACITY
MAGNETIC SEPARATOR			P		CONCENTRATED MAGNETIC FIELD						P							WATER, IRON POWDER	P	P		HIGH FIRST COST, HIGH SKILL REQUIRED, SPECIALIZED APPLICATIONS, LOW CAPACITY
ELECTRO-STATIC SEPARATOR			P		HIGH TENSION ELECTRIC FIELD											P		ELECTRICAL CHARGE	P			HIGH FIRST COST, HIGH SKILL REQUIRED, SENSATIVE TO AIR HUMIDITY, PRODUCT MOISTURE & TEMPERATURE OF BOTH, SPECIALIZED APPLICATIONS, LOW CAPACITY
RESILIENCY SEPARATOR			P		HARD, INCLINED SURFACE							P							P			SPECIALIZED APPLICATIONS, VERY LOW CAPACITY

TROUBLE SHOOTING IN SEED PROCESSING

Z. A. Stanfield and Howard E. Reeder[1/]

In these days of rising costs, higher taxes, less work, and more play, the seedsman still has to keep his nose to the grindstone. He continues to perpetuate, nourish, protect, and try to improve those God given life forces in our cultivated crops from generation to generation. But ballooning inventory values and rising interest rates seem to act as a giant magnifying glass to make major troubles today out of yesterday's irritations. Those of us in seed processing can help out by shooting down some of the troubles which creep up in our areas of activity. I am going to analyse the steps in a procedure for trouble-shooting and give you a few examples in which these steps have been helpful to us. I hope that you will find one or two points which will be helpful in your "trouble-shooting" activities.

"TROUBLE-SHOOTING" DEFINED

To me "trouble" is some adverse deviation from a desirable standard condition. "Shooting" implies aiming at, firing at, and hitting some adverse target. So in business "trouble shooting" can be defined as the activity of detecting and correcting adverse deviations from standard conditions. The owner himself or the manager may be a troubleshooter; or he may assign this task to others. A process engineer spends a lot of time troubleshooting. Troubleshooting is one type of hunting in which the weapons do not have to be registered.

[1/] Mr. Stanfield and Mr. Reeder are associated with Funk Brothers Seed Company, Bloomington, Illinois.

PROCEDURE

I shall discuss four major steps in troubleshooting: (1) set standard, (2) detect variations from standard, (3) make corrections, and (4) follow through. Let's analyse each step in more detail.

Set Standard:

Important standards in processing relate to quality of product, safety of operating personnel, and profit. All of these standards are components of larger goals set by the management of the company or organization. For example, a standard operating air temperature of 105°F. in seed drying is a step toward achieving a quality of higher than 95% germination for the final product. A desired maximum number of lost-time hours per thousand man-hours worked in a department is a standard related to an overall company goal of having a safe place to work. Budgets and standard costs are standards related to the overall goal of company profit as set by management. It is important to know these standards, to know how and why they were set, and to know how the standards are related to the overall company goals. A good trouble-shooter is goal-oriented. The three areas mentioned: Quality of product, safety, and profit, relate to the interests of three important groups: customers, fellow employees, and stockholders.

In setting standards, it is important to use numbers to the greatest practical extent.

Detect Variations from Standard:

Variations from standard may be detected from many sources.

Lab reports: Most seed companies have routine procedures for sampling and testing each lot of seed and reporting the results to a designated person of authority. Variations from standard should be reported immediately (verbal or phone) by the laboratory supervisor prior to typing or mailing of reports.

Complaints: Customer complaints generally are reported to the Sales Department. Sales Managers have a natural instinct to hide or delay these reports. However, a customer who complains must be considered a friend of the company or industry. For every customer who complains, there are ten customers who say nothing but buy elsewhere. A complaint is an asset to a good troubleshooter. A little technical service may be all that is needed but the complaint may be a symptom of more serious trouble.

Inventory Reports: These reports in finished form generally come to a sales and/or accounting department. Over-production of a size or type of seed will show up here.

Insurance and Accident Reports: The reports by outside persons are valuable sources of information on potential hazards to operation and employee safety.

Budgets and Cost Reports: These reports are most valuable if prepared rapidly (by the 10th of the following month) and in such a form to show variances from standard. Monthly variations of, say, $500 or 5%, whichever is greater, should be forcefully analyzed.

Plant Tours: A visual inspection on a periodic schedule basis will do a great deal to supplement written or verbal reports.

Verbal Reports: Meetings for discussion of operations with groups and/or informally with individuals can reveal unwritten variations from standard.

Two important features in detecting variations from standard should be stressed: (1) speed of detection (try to recognize variations before formal reports are issued) and (2) reliability of information (check or verify all reports).

Make Corrections:

There are several important points to consider in making corrections in variations from standard. Goal orientation should be kept in mind at all times. Correct as fast as possible.

Define Problem: A clear-cut numerical statement of the degree, nature, and desired result is over half the battle.

Data-Data: Get as much information as time allows. Usually, the facts will describe the solution. There is a lot of just plain work here.

Solutions-Innovations: Solutions usually can be obtained from your own personnel. Operators close to the problem usually know the solution if they have experienced the same problem before. If it is a new problem, try your own resources first-operators, managers, yourself-then go to your friends: (1) equipment or material suppliers (the seed industry is blessed with talent), (2) your trade association (the seed industry again is above average), and (3) universities (maybe try them first!). Give full and honest credit to the originators of solutions to problems - janitor, operator, president, or yourself.

Economic Studies: A solution usually will require investment of money and you must be able to relate this investment to your company's profit goals. Compare alternative solutions using economics. Most seed companies will have a method for economic evaluation: payout time, rate of return, present worth, etc. A good troubleshooter must know these statements:

1. Participation of operating personnel in the design of systems or procedures for correction of deviations in their departments will enhance success of the intended correction.

2. Full answer to the question "Why?" by an operator will insure cooperation by the operator in his participation to the correction of a deviation.

Sell-Spaced Repitition - A processing man usually does not consider himself to be a selling man. However, when an innovation is involved for making corrections, the process man must sell. Particularly if large investments or new methods are involved, he must sell.

The technique in selling of spaced repitition usually will be successful. This, simply, means stating the solution-pausing for a time (days)-stating the solution-pausing, etc. This cycle generally must be repeated six times for success. The first response is negative and subsequent responses become more positive until success is realized. Successful troubleshooting requires selling of ideas.

Proposals: After the operating personnel are sold on an innovative correction (or any correction to a variation), formal proposals in the form of recommended changes in procedure or proposals for capital investment can be made. Most companies will have some procedure to follow.

Reduce to Practice: After the foregoing procedures, this step will seem inconsequential, or ordinary, but it is, of course, the the main step. The point is that the foregoing steps have reduced the chance of failure of our solution. These previous steps have, in fact, insured the success of our venture in trouble-shooting. If new equipment is installed or new procedures adopted, the operators will make it work!

Follow Through:

After corrections have been made, it is necessary for the troubleshooter to follow-through for a period of time (usually one year) to validate the solution.

Laboratory reports of routine analyses will indicate success of the changes.

Meetings of staff and management personnel will indicate their opinion of the degree of success of the solution.

Cost reports will clearly give a "post-audit" of the project.

In all cases, teamwork of all affected personnel has been responsible for the success of the "trouble-shooter's" work.

Frequently, new projects will be developed from certain required corrections or changes. Thus, the cycle of improvement of conditions to meet company goals is extended.

EXAMPLES

And now, let's examine some practical examples of "trouble-shooting" in seed processing.

A list of processing steps reveals many chances for damaging seed. Seed companies exert maximum effort to hold damage at a low level in each step.

Shelling:

Damage in shelling may be held to a minimum in impact shellers by shelling at the proper moisture content, by holding speed down to a practical minimum, and by adequate feed rate.

Development of a production-line sheller which would approach hand shelling with a minimum of crown damage would appear to be a desirable goal.

We have been attempting to develop a method for measuring seed damage which would in some way relate to the vigor of the seed or show the effect of damage on vigor. GADA and TZ tests on seed hand shelled and machine shelled showed no significant difference. However, by applying stress of heat and humidity to the seed and comparing vigor readings before and after stress we began to see differences in samples shelled by different methods. We are still trying to develop this method. We call it the "vigor-index", or Funk "vigor index." (Figure 2)

In effect, we have borrowed the accelerated aging test (presented here at the Short Course) and substituted the germinations before and after stress with vigor measurements (GADA or TZ).

I would like to show you some of the preliminary work we have done with this test. We still have a long way to go. We have constructed an experimental sheller in which we attempt to simulate hand shelling mechanically. Perliminary results are promising but we have not established capacity factors yet.

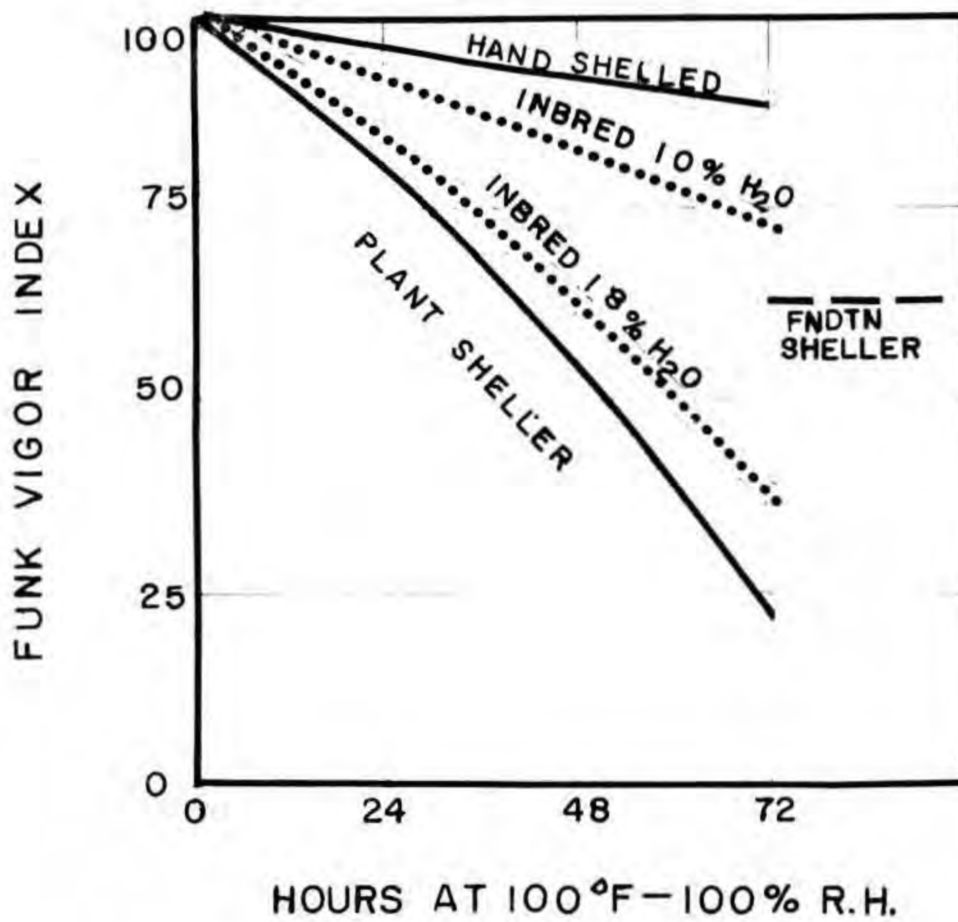

Figure 2. Effect of shelling methods on Funk vigor index (initial GADA ÷ final GADA x 100).

The example is given merely to show a case of attempting to set a standard (hand shelling) and establishing some method of measuring deviations from standard (vigor-index) which relate to effect of damage on seed vigor, and attempting to make corrections with a new sheller design.

Storage:

A certain percentage of seed stored in a warehouse will deteriorate so that germination falls below a desired standard, such as 95%. This effect is detected by routine or periodic sampling of the inventory. Discard of this seed constitutes an economic loss to the seed company.

Inspection of the equilibrium moisture content chart for corn reveals how changes in temperature and relative humidity in the warehouse can cause raising and lowering of the moisture content of corn. (Figure 1)

Frequently it is possible to justify capital expenditure for equipment to control the atmosphere in a seed warehouse by lowering the amount of discards due to low germination; each seedsman must, of course, consider his own conditions, area of country, etc., but rising costs of seed in storage has been a factor justifying control where perhaps this expenditure could not have been justified at lower values of inventory.

Pallets:

Setting standards of labor usage in warehousing and shipping has led many companies to the use of pallets and fork lift trucks in place of the more costly hand-stacking methods.

In three warehouses, we purchased enough pallets to "pilot-plant" the use of pallets to demonstrate the advantages and to obtain data with which to justify further conversion to fork trucks and pallets. In this way, the plant supervisory personnel participated in the project by having their own experience to use in estimating cost savings and other benefits.

After converting to pallets, we obtained monthly reports from the plants to determine if anticipated savings were actually being realized.

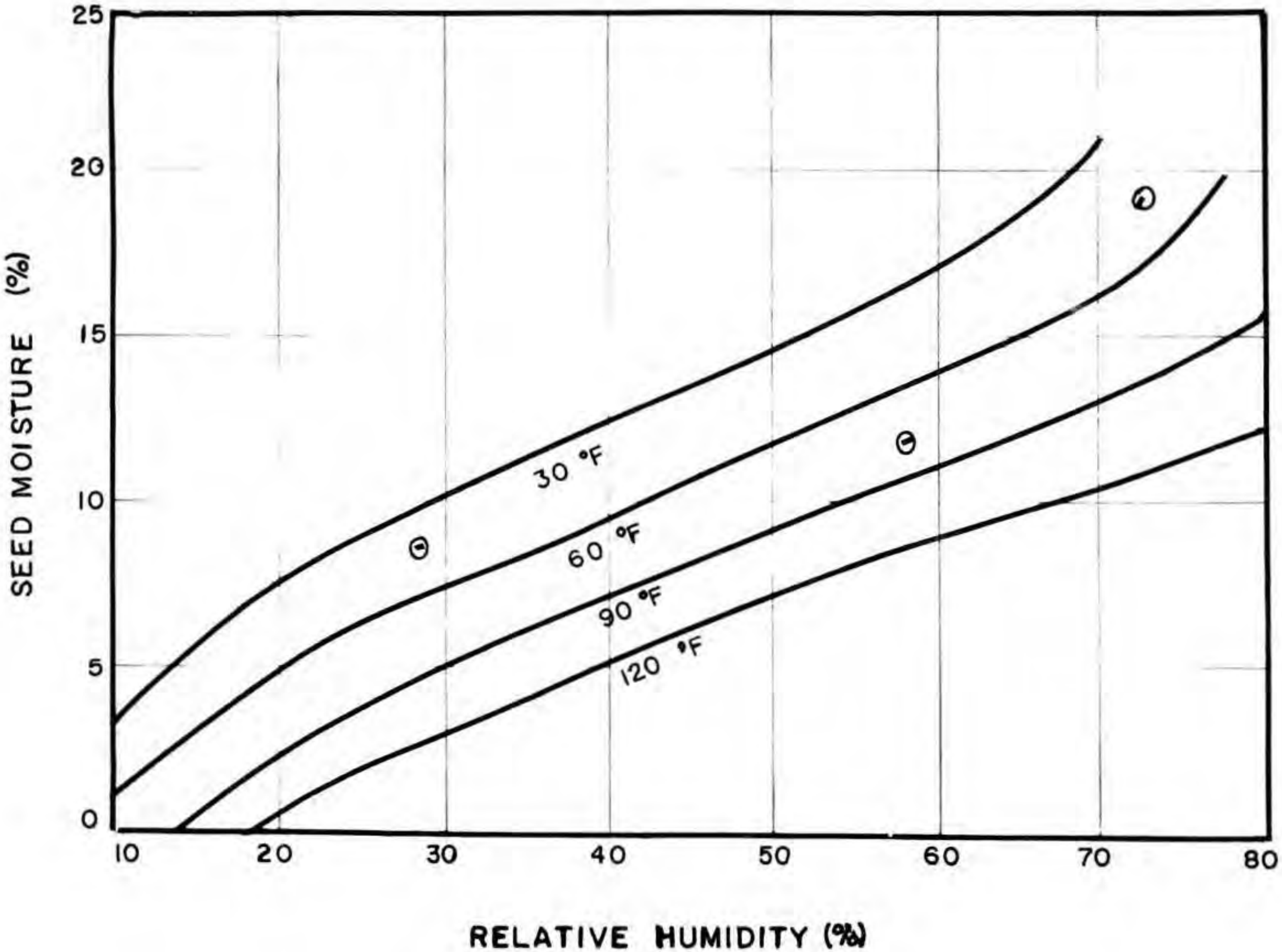

Figure 1. Equilibrium moisture content - corn.

Sales-Capacity Balance:

Setting standard desirable ratios of dryer capacity, storage capacity, and processing capacity to expected sales from a plant can be helpful. Comparing these standard ratios with actual capacities at existing plants reveals bottlenecks or critical areas and is helpful in planning.

Economic studies will show the desirability of correcting these variations, usually by new construction, as shown by this project now underway in Canada for added drying and warehouse capacity.

Planter Plates:

An outstanding job of troubleshooting has been done by the ASTA Machinery Committee in working with the implement manufacturers and seed companies in guiding the development and testing of planter plates and following through year after year to improve plates for the many odd kernel sizes and shapes.

Foundation Seed Corn Dryer:

Our Foundation Seed personnel assigned us the task of designing and building for them a dryer system so that they could load the dryer bins in the seed-corn field and reduce damage. In this example they were attempting to meet new operating cost standards and quality standards. After hours and hours of meetings, caluclations, and economic studies, the system finally was proposed, approved, built, and operated with the desired results. The photos will tell the story briefly.

Air Pollution Control:

In this example, our standard for emission was set by the State of Illinois. Their formula for allowable emission is based on process weight rate as shown on the curve. (Figure 3)

Our job was to determine our deviation from their standard. We made material balances around whole plants by sampling process streams and making measurements as required. Emission was calculated in this way. Examples are shown in the slides. In every case our estimated emission rates were within allowable limits.

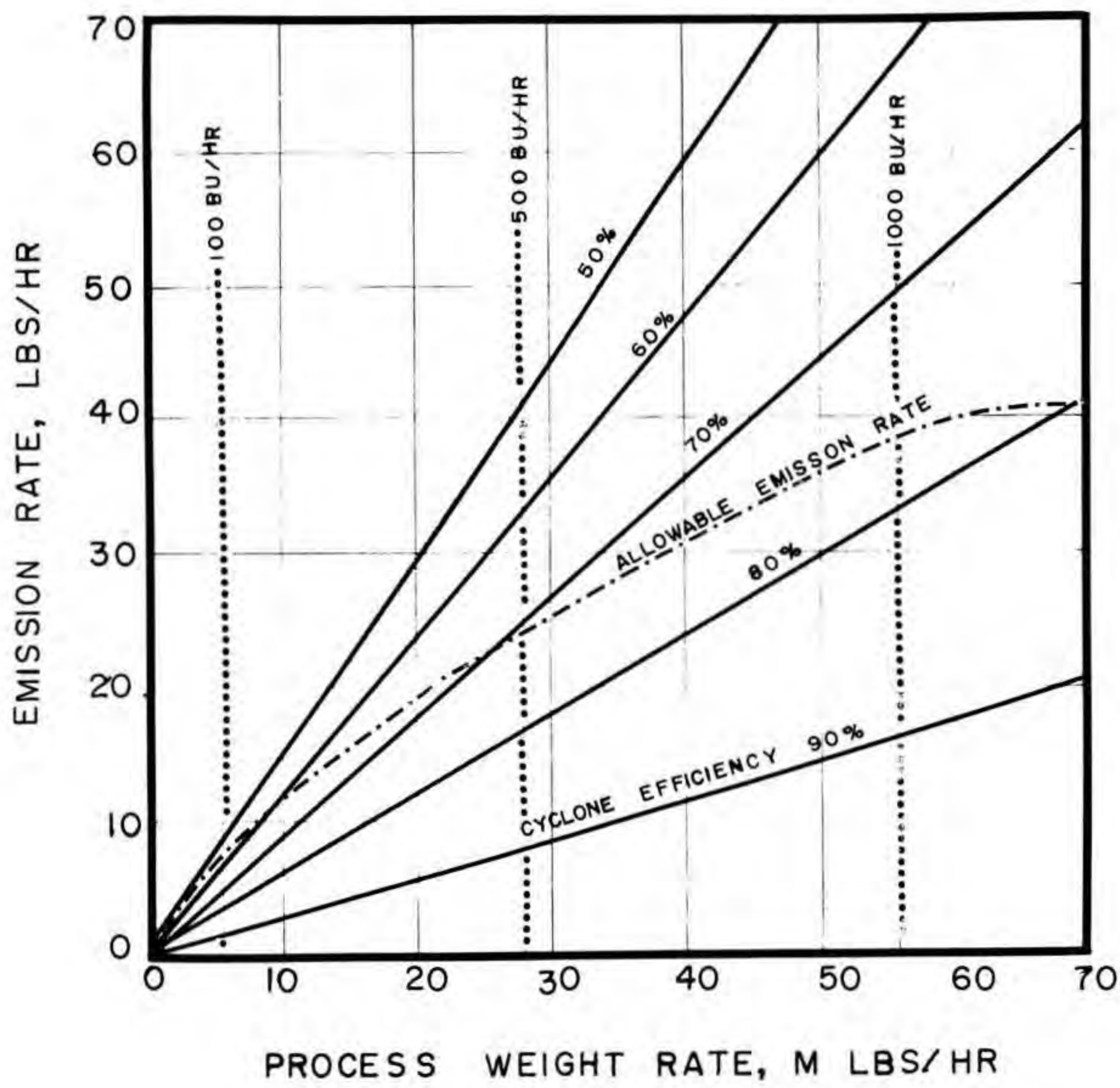

Figure 3. Effect of cyclone efficiency on calculated rates of emission and comparison with allowable emission rates (state of Illinois Rules and Regulations, March 30, 1967).

So no corrections were necessary. We followed through by reporting to the State Board, as required by law.

This study revealed two principle points: (1) generally a seed processor in Illinois can achieve satisfactory results by properly designed cyclone dust collectors, as shown here; also, (2) the seed industry is quite different from the grain handlers in process weight rate and cleanliness of input seed.

CONCLUSION

I am sure you can describe many examples of successful troubleshooting from your own experience. In the examples I have given, I am sure you have noticed most of the four steps shown here: (1) Set Standard, (2) Detect Variations from Standard, (3) Make Corrections, and (4) Follow Through.

I hope this formula will some day be helpful to you in "trouble-shooting" your way out of a tight spot. Thank you.

COMPLIANCE WITH SEED LAW

Charles Sciple[1/]

Failure to label in accordance with the requirements of State and Federal Seed Laws can become a major expense in time and money. It can be embarrassing and result in a loss of valuable customers. When labeling seed for sale, seedsmen must follow established labeling procedures and become familiar with State Seed Laws of the State into which the seed is intended for sale.

Regardless of effort it seems that some seedsmen continually find themselves in trouble with seed control officials, and there are all kinds of excuses for this. A close look at the seed industry indicates that most of the businesses do comply with the State and Federal Laws, and it is difficult to see why others find compliance so difficult. My experience has been that most of the violations occur in businesses which handle seed as a sideline or, in other words, in businesses where selling seed is not the primary source of income. This indicates to me that the business is geared for some operation other than a good sound seed business. It may be a feed store, a hardware store or some other farm-type enterprise. Converting combine-run seed into good marketable seed for disposition on today's competitive market, however, requires considerable know-how and good, sound practices which may be lacking in some businesses where seeds are of secondary importance.

The seedsman must understand the standard basic lableing procedures before attempting to make a label. A label must be practical as well as legal. We might cite, as an example, statements such as "Pure seed not less that 90 percent" or "at least 90 per cent in germination." Many states maintain that such statements are false. If actual test results shouldhappen to fall below the "guaranteed" figure, many states do not allow a tolerance and the seed is declared to be falsely labeled. Some of you may remember many years ago when law mixtures were permitted to be labeled as a complete

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[1/] Mr. Sciple is Assistant Agronomist and Assistant Director of the State Seed Testing Laboratory, State College, Mississipi.

analysis for each component part in the mixture. Can you imagine the confusion to a home owner when he read a label bearing the complete analysis for each kind of seed in a four-or five-way mixture?

SEED PROCESSORS AND LABELERS MUST KNOW THEIR PRODUCT

A seedsman must be able to identify seed most often found in his area as to whether it is a crop or a weed. In addition he should be able to look at a handful of seed during processing and quickly determine if the machinery is performing properly.

The lack of uniformity within a seed lot ranks near the top as the main reason for failure to meet state and federal labeling requirements. A seed lot must be uniform in order for tests to be representative for quality of the seed in the lot.

KEEPING GOOD RECORDS IS ESSENTIAL TO ANY SUCCESSFUL SEED BUSINESS

Many of today's seed operations are too large for the operator to remember the details of all lots of seed he sells or intends to sell. Not long ago, I contacted a wheat seedsman because of a compliant by one of his customers that he had failed to get the variety ordered. I asked the seedsman to show me where each of the three varieties he handeled were stored before processing. He could not show me the storage area nor could he produce any records or other identifying marks for the wheat which he had marketed. Surely, accurate records would help to prevent this and other similar situations.

All wheat samples collected by state inspectors in Ohio were planted during each of the past three years. Most violations resulted from seed mixtures. Certainly the farmers and processors did not mix the wheat intentionally, but most of the errors came about either because poor records or no records at all were maintained.

It is difficult to study all state laws and become familiar with each state official's interpretation of that law. Sometimes we don't interpret what we read the same as someone else might. I believe it is best that you visit with your state control official and discuss changes you propose to make in labeling before printing the labels. Once you have decided on a definite label, send it to the state and federal official and ask if the label meets the labeling requirements for the state into which you intend to ship seed.

SUMMARY

1. A seed dealer must put his business in order and follow sound business practices. The seed business is not something you get into and out of quickly. You cannot fool the farmer into buying low quality seed and expect him to be happy year after year. He may get a good stand this year and not notice the weed problem now, but what about next year? Perhaps he bought seed from you because he trusted you. You let him down and you have likely lost a customer.

2. A seedsman must know his product. You cannot guess at the germination or estimate the weed seed content. You must test to determine the quality. The seed lot must be labeled properly to reflect its quality as determined by testing. You cannot expect to label low and meet competition and you cannot expect to label high and stay out of trouble. The label must reflect the actual quality of the seed.

3. The seedsman must keep a good set of records and not depend on memory alone. Records can be the seedsman's salvation should he be required to defend the quality of the seed sold in court. Records establish proof of correctness of labeling intent and permit the seedsman to make corrections based on facts where needed.

4. Seedsmen should frequently consult with seed control officials and discuss their labeling problems. Seed control officials should be informed of labeling changes before the changes are made. A control official enjoys working with seedsmen who make a serious effort to label correctly.

GLUTAMIC ACID DECARBOXYLASE ACTIVITY (GADA)[1] AND SEEDLING GROWTH MEASUREMENTS AS TESTS FOR SEED QUALITY

Charles C. Baskin[2]

GADA

Glutamic acid decarboxylase activity (GADA) is a test that measures the activity of one specific enzyme rather than a system of enzymes as does tetrazolium. The level of enzyme activity is determined by the amount of carbon dioxide (CO_2) given off and is positively correlated to seed quality, i.e. the more CO_2 given off the better the quality of the seed.

GADA appears to be better related to seed quality of grain rather than to quality of dicotyledonous species such as soybeans, cotton, etc.

GADA is closely related to the storability, root growth and yield of corn (2,3). Grabe (3) and Gill (1) have shown yield decreases of 8% and 14% respectively between high and low GADA in corn. Relationships exist between GADA and seed quality in oats, wheat and rice (4).

The equipment needed for this test is relatively inexpensive. It consists of a water bath for controlling temperature, simple, easy to make manometers, a scale for measuring manometer fluid movement, small containers (1/2 pint jars) and a small grinder.

Some of the advantages of GADA test are:

1. It is simple and easy to conduct.
2. It does not require a large investment in equipment.
3. It can be completed in a short period of time.

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[1] Complete procedures for GADA are available on request from the Seed Technology Laboratory, P. O. Box 5267, State College, Mississippi 39762.

[2] Mr. Baskin is Assistant Agronomist, Seed Technology Laboratory, Mississippi State University.

Crop varieties differ in GADA; therefore, comparisons for quality must be made within varieties and not between varieties. Also, GADA is too sensitive to be used as an indicator for stand establishment.

GROWTH RATE TEST

Growth rate tests will probably be well adapted and easily incorporated into a regular germination testing program.

Some advantages of grwoth test are:

1. They are simple and easy to conduct. Any technician can conduct growth tests.
2. They can be incorporated into a germination testing program at little or no expense.
3. Most growth rate tests can be easily standardized.

First Count:

This test can be incorporated into the standard germination test. The number of normal seedlings removed when the preliminary count of the germination test is made is an indication of the quality of the seed lot. The higher percentage of normal seedlings removed at the perliminary count the better quality the seed lot.

If the first count is to be used to compare different lots of seed over a period of several months, all first counts must be made at the same time interval after planting.

Speed of Germination:

If a more detailed test is desired, speed of germination may be used. This test can be incorporated into the standard germination test, but will require more time to evaluate than a regular, standard germination test. After the seed have begun to germinate they must be checked daily at approximately the same time each day. Normal seedlings are removed from the test when they reach a predetermined size. This procedure is continued until all seed that are capable of producing a normal seedling have germinated.

An index is computed for each seed lot by dividing the number of normal seedlings removed each day by the day on which they were removed after planting. Thus quality indexes of 15 (lot A) and 23 (lot B) are obtained in the following manner:

$$\text{Lot A: } \frac{\text{no. seedlings removed daily}}{\text{day after plant.}} = \frac{0}{1}+\frac{0}{2}+\frac{0}{3}+\frac{8}{4}+\frac{10}{5}+\frac{24}{6}+\frac{28}{7}+\frac{24}{8} = (0)+(0)+(0)+(2)+(2)+(4)+(4)+(3) = 15$$

$$\text{Lot B: } \frac{\text{no. seedlings removed daily}}{\text{day after plant.}} \quad \frac{0}{1}+\frac{6}{2}+\frac{12}{3}+\frac{24}{4}+\frac{45}{5}+\frac{7}{6} = (0)+(3)+(4)+(6)+(9)+(1) = 23$$

Lot B would be considered the better quality of the two lots since the higher index indicates seed quality.

Root and/or Shoot Growth:

Another growth rate test that may be easily employed is root length or shoot length or both.

This test involves the measuring of the length of root (or root and hypocotyl) or shoot at a specified number of days after planting in the germinator. When using this system of comparison, the lot making the most growth is considered to have the highest quality. Only normal seedlings should be measured.

Root and/or shoot growth can be employed with grasses and grains. However, dicots will probably have to be limited to root or root and hypocotyl growth because of the slowness of epicotyl elongation in many dicot species.

The tests we have discussed thus far can be conducted in the laboratory with no additional equipment other than that required for standard germination tests.

In order to make valid comparisons of these tests both the conditions of the test and the conditions of germination must be very carefully controlled. If some replications become dry, for example, growth will be slower and the results of the test will be biased. If alternating temperatures are used the time of day when the tests are placed in the germinator will affect the result. For example, corn is germinated at an alternating temperature of

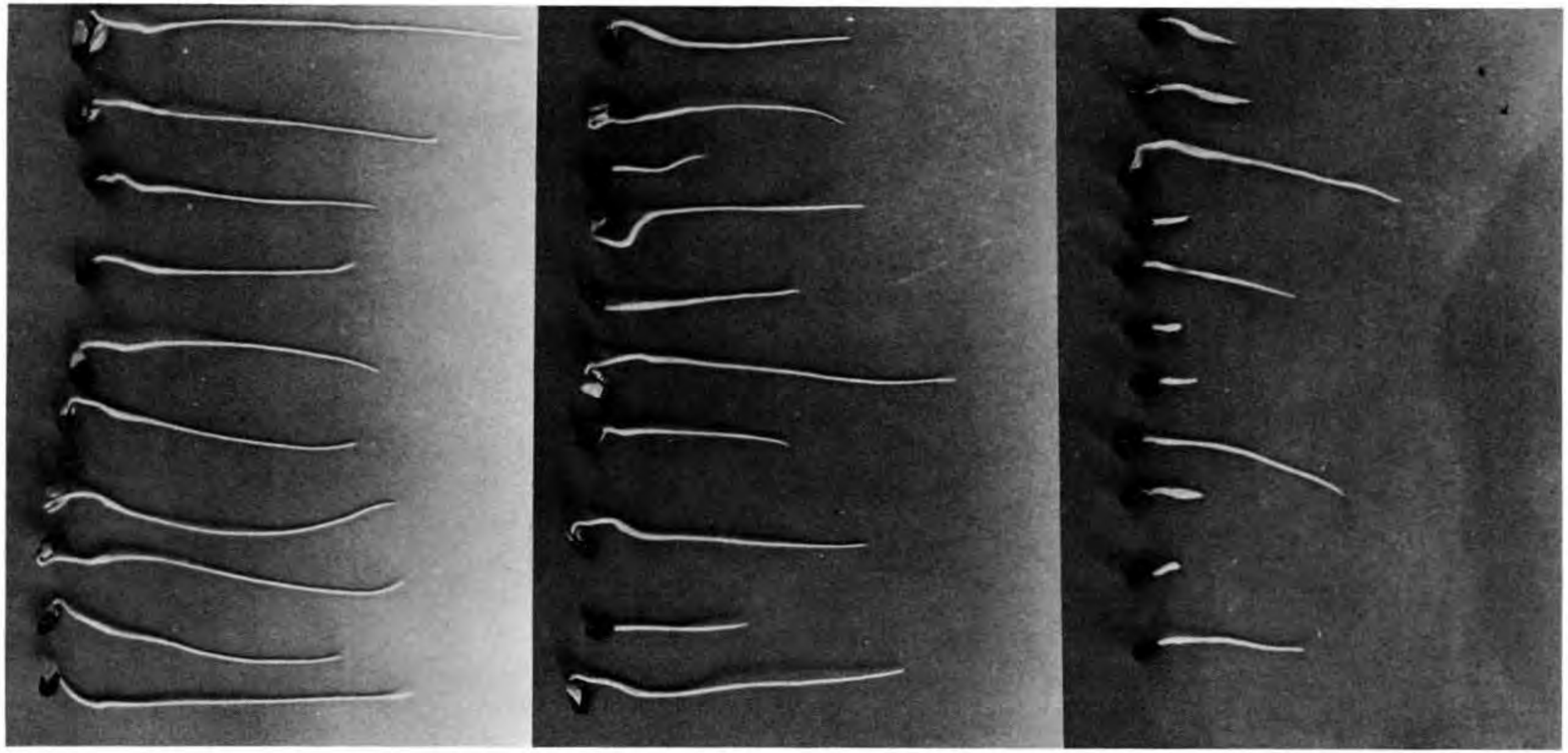

Figure 1. Differences in root growth indicating differences in seed quality. Top, high quality seed minimum deterioration, middle, seed lot beginning to deteriorate. Note, increased variation reduced growth of some seedlings. Bottom, seed lot too highly deteriorated germination about 60%.

20° - $30^{\circ}C$. If tests are placed in the germinator at the beginning of the $30^{\circ}C$. cycle and are compared with tests placed in the germinator at the beginning of the $20^{\circ}C$. cycle, we would expect the test which was begun at $30^{\circ}C$. to make more total growth than the test which was begun at $20^{\circ}C$., when measurements are made the same number of hours after the beginning of the test. If laboratory growth tests are to be used it would be well to consider using a constant temperature to avoid this problem.

Speed of Seedling Growth and Seedling Weights:

Several variations of laboratory growth rate tests may be used.

Total seedling growth in the greenhouse or field may be measured at a specified number of days after planting. The lot of seed producing the most growth per normal seedling is considered to be the best quality. Seedlings may be cut and weighed, fresh or dry, for additional information. Seedlings producing the most weight are considered to come from the better quality seed.

Emergence test will require additional facilities, mostly field plots and greenhouses and other investments outside the laboratory. Conditions in the greenhouse or field are much more difficult to control than those in the laboratory; therefore, results can be expected to be more variable.

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SOME ASPECTS OF SEED DETERIORATION AND POTENTIAL STRESS VIGOR TESTS

Harold W. Byrd[1]

As seedsmen, I'm sure you have observed that although seed lots of the same crop may germinate equally well in the standard germination test, they don't always perform the same in storage or in the field. This, of course, is because these seed lots vary considerably in the amount of deterioration that has taken place, i.e., they vary in potential seedling vigor. Therefore, since loss of germinability is one of the last symptoms or phases of seed deterioration, the standard germination test has no way of detecting how much deterioration has occurred until the seed are already non-germinable.

Now with your permission let us consider some of the deterioration patterns seeds follow as they die. Utilizing the tetrazolium test for seed viability, the pattern of deterioration in soybean seed was studied in the Seed Technology Laboratory (Table 1 and Figure 1). After hand harvested soybean seed were artificially aged for various lengths of time, total formazan production was determined for each level of deterioration using two procedures:

1. Pre-staining - Seeds were stained intact, then ground in a Wiley mill and the formazan extracted with acetone. Visual observations of staining patterns were also made.

2. Post-staining - Seeds were ground in a Wiley mill, then stained and the formazan extracted with acetone. Formazan production was determined quantitatively with a spectrophotometer in both cases.

As one can see in Table 1 and Figure 1, there is quite a contrast between the two procedures. In the pre-stained method, formazan production increased (decreased transmittance) as the level of deterioration increased up to the point where germination started to

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[1] Mr. Byrd is Assistant Agronomist, Seed Technology Laboratory, Mississippi State University.

Table 1. Comparison of standard germination, root growth, and formazan production of various deterioration levels of soybean seed.

Trt.* Days	Std. Germ. %	Root Growth** mm.	Formazan Prod. (% transmittance) Pre-stained	Post-stained
0	96.5	106.5	68.0	42.0
5	97.5	98.0	----	57.0
10	99.0	104.8	62.0	61.0
15	97.5	81.9	61.0	68.5
20	88.0	75.3	56.0	68.5
25	96.0	74.3	53.5	72.0
28	78.0	64.8	51.0	72.5
34	72.5	-----	65.0	74.5

* Days aging at 38°C. in sealed jars with 12.3% seed moisture content.

** After 4 days at 25°C.

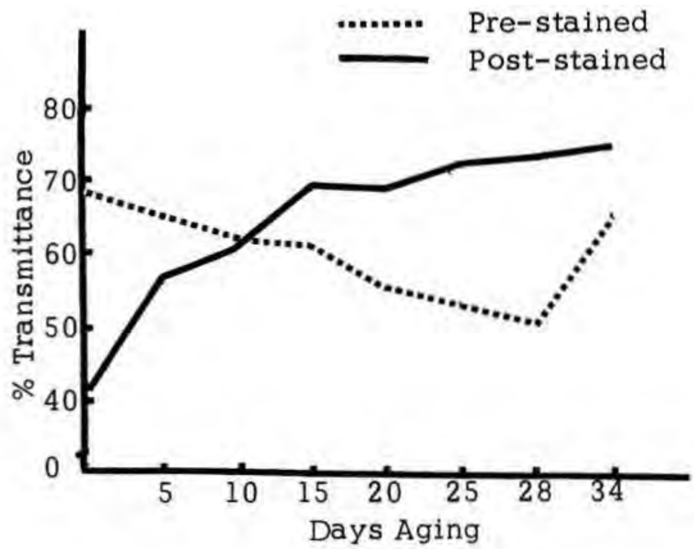

Figure 1. Comparison of formazan production in pre-and post-stained soybean seed.

decline, then decreased rapidly. This illustrates that as deterioration progressed, seed became more permeable and the penetration of the stain increased (illustrated by increased color intensity). This was also detected by visual observation. However, once the stain completely penetrated the cotyledons and the surface layers began to die, total formazan production began to decrease (increased transmittance).

On the other hand, in the post-stained method formazan production decreased progressively with increases in seed deterioration. This, of course, was due to all the seed tissue being in contact with the tetrazolium solution, i.e., there was no penetration effect.

Thus, with the use of the above techniques together with visual observations, we find that seed permeability (increased penetration) increases with deterioration. This penetration continues until the staining solution completely penetrates the cotyledons during the staining period. Then, the surface layers of the cotyledons and the tip of the radicle begin to die. As deterioration progresses, the surface layers of cells die giving the seed a milky white appearance, and this continues until all the cells of the seed are dead.

In various other studies it has been observed that deterioration quite often begins at the sites of mechanical injuries, morphological weaknesses, and occasionally at the margins of the cotyledons or other surface areas. These necrotic areas progress outward until the entire seed is dead.

Now that we better understand how seeds deteriorate, let us consider some tests with which one can detect the level of deterioration of a given seed lot. These tests for deterioration (vigor tests) can be divided into: (1) stress tests; (2) enzymatic tests; and (3) growth tests. Today, we will consider only the stress tests.

A stress vigor test, as the name implies, is a test whereby unfavorable environmental conditions are applied to seed in order to determine specific performance characteristics. The two most promising stress tests at the present time are the accelerated aging and cold test. First, let us consider the accelerated aging test.

ACCELERATED AGING TEST

The seedsman is quite often faced with the decision of which lots from among many available should be marketed first and which lots should be held for possible carry-over if the market is not strong, or as a hedge against shortages the following year. If seedsmen have at their disposal only the information from the standard germination test, they have no way of knowing how much deterioration has taken place in the various seed lots although the germination percentage is high in all of them. Very often seed lots are selected at random for carry-over, and the seedsman finds the next season that several of them did not carry-over so well. Of course, this all illustrates the tremendous need for a reliable vigor test which would furnish seedsmen with valuable information concerning the quality status of their seed lots.

The accelerated aging test shows great potential as a possible test for predicting the storability of seed lots. This test operates on the theory that the degree of deterioration is variable among seed lots of a given kind, even though deterioration has not progressed to the point where it has affected germination. Thus, if small samples of various lots of the same seed kind and approximately the same germination percentage are subjected to extreme stress storage conditions, i.e., high temperature and relative humidity, for a short period of time, the badly deteriorated lots will decrease drastically in germination while high quality lots show no appreciable drop in germination. For most seed kinds, we have found that the best stress conditions are 100% relative humidity and temperatures of 35° to 45°C. for a period of 2 to 8 days. Some typical data obtained in the Seed Technology Laboratory are given in Tables 2, 3, and 4.

Equipment:

The accelerated aging chamber we are using was made from an old, water cooled germinator with 2 1/2" insulated walls and door. It has inside dimensions of 26" width, 24" height, and 20" depth. All water tubing and other internal equipment- except tray racks - were removed from the germinator. All gaskets, holes, etc., were sealed with 3M weather strip adhesive (black). A water reservoir approximately 1 1/2" deep is maintained in the bottom of

Table 2. Comparison of standard germination, greenhouse emergence, seedling height, and accelerated aging results of various deterioration levels of onion seed.

Trt.	Std. Germ. %	A.A. * %	Ghs. Emergence %	Seedling Height mm.
7-0	91.0	91.5	93.5	51.0
7-1	85.5	91.0	93.5	65.3
7-2	90.5	89.0	91.5	50.2
7-3	89.5	85.5	92.5	53.2
7-4	82.5	76.0	91.0	43.2
7-5	85.5	67.5	88.5	43.5
7-6	86.0	32.5	88.0	38.2
7-7	81.0	10.5	86.5	36.0

* 5 days at 42°C. - 100% R.H.

Table 3. Comparison of standard germination, accelerated aging, and cold test performance of various deterioration levels of soybean seed.

Trt. Days	Std. Germ. %	A.A. * %	Cold Test** %
0	96.5	90.0	82.5
5	97.5	80.5	85.5
10	99.0	73.0	79.5
15	97.5	29.5	27.5
20	88.0	24.0	25.5
25	96.0	18.0	12.5

* A.A. at 42°C. for 2 days.
** 5 days at 13°C.

Table 4. Germination percentages of corn and tall fescue seed lots after accelerated aging and intervals in open storage.

Lot No.	Initial Germination	Accelerated Aging	Open Storage (Months) 6	12
		CORN		
1	100	94[a/]	100	98
2	100	92	99	98
3	92	44	90	74
4	84	22	94	78
5	96	19	96	22
		TALL FESCUE		
1	95	94[b/]	96	93
2	92	83	92	52
3	87	80	90	48
4	88	56	73	24

[a/] Accelerated aging 42^{o} - 100% R.H./144 hours.
[b/] Accelerated aging at 40^{o}C. - 100% R.H./84 hours.

the chamber. In the water reservoir is a flexible, immersion heating rod. Temperature is controlled by a thermister temperature controller equipped with a general purpose thermister probe.

A plexiglass chamber was designed as an insert or liner for the chamber to maintain a more constant temperature and relative humidity. The plexiglass liner fits on a rack about 5 inches from the bottom of the chamber and 2-4 inches from the side, walls, back and ceiling. The liner has a water reservoir, glides for 2 trays, and a removal access panel in the front. The top rack of the plexiglass liner is covered with blotters to collect any condensation

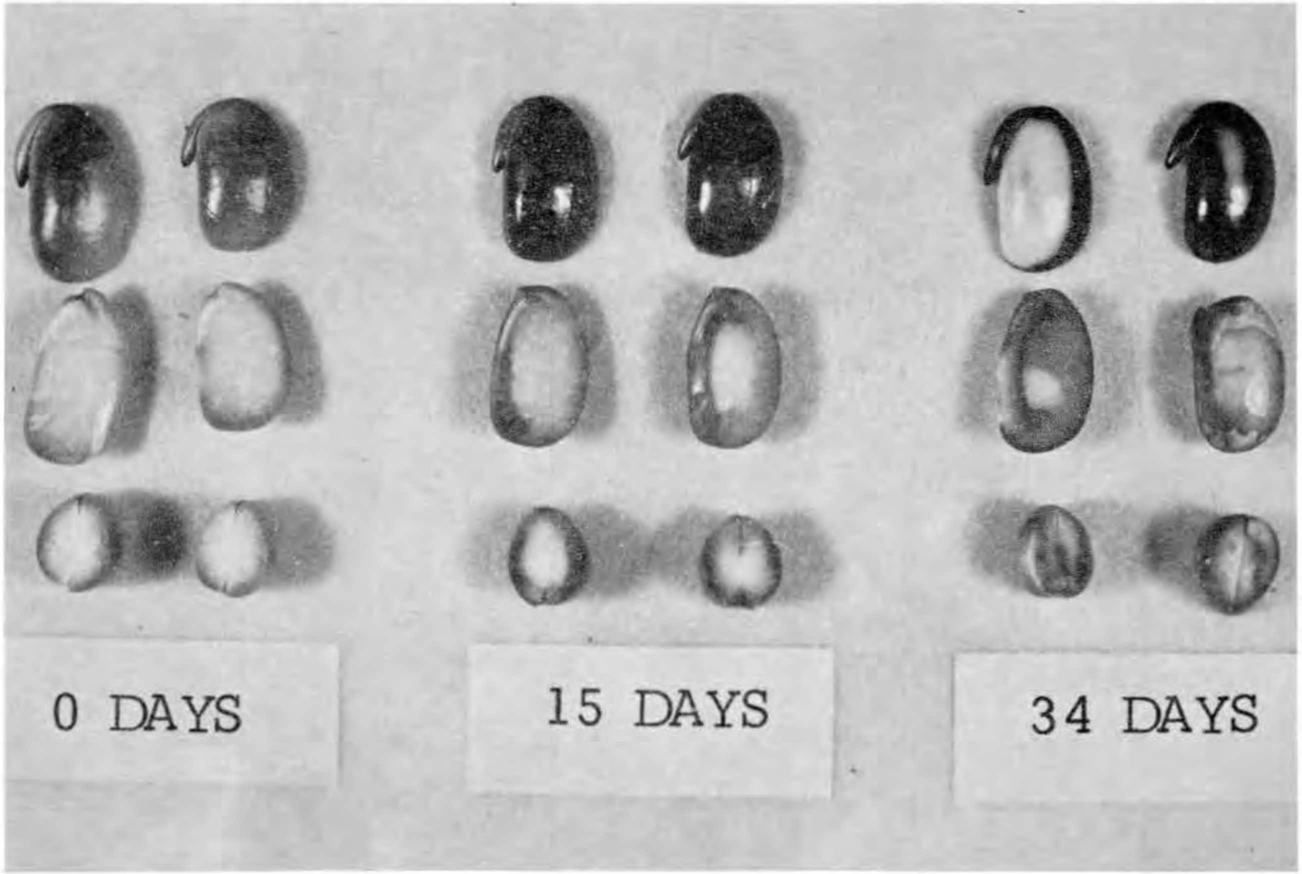

Figure 2. Tetrazolium staining patterns of soybean seed after 0, 15, and 34 days artificial aging.

dripping from the top (actually, very little condensation forms on the top or walls of the liner). The bottom rack is used for holding the samples of seed at a distance of 3 inches from the surface of the water. A long stem dial thermometer is inserted through the front access panel of the liner, and a sensitive glass mercury thermometer is attached to the sample tray placed in the liner.

In operation, water is placed in the bottom of the chamber and plexiglass liner. The temperature controller is energized and adjusted to the desired temperature setting with the glass thermometer inside the liner. After the desired temperature is achieved, the tray is removed and samples to be tested are prepared and placed in small wire screen baskets on the tray. The tray is placed in the liner and accelerated aging begun. After accelerated aging for the desired number of hours or days the samples are removed and standard germination tests are made on the samples.

COLD TEST

The cold test is a stress test whereby seeds are subjected to cold, wet conditions in order to obtain some insight as to the ability of seed lots to emerge under unfavorable conditions frequently encountered during the spring planting season. This test also shows potential for predicting other phases of field performance, such as plant growth rate and yielding ability.

The procedure used for the cold test in the Seed Technology Laboratory is: (a) seeds are planted in a soil-sand mixture (usually 1/2 sand and 1/2 top soil from a field in which the crop being tested has been grown the previous year). Fifteen hundred grams of the soil mixture are placed in plastic crispers, the seed planted on top, then covered with 1000 grams of the soil mixture; (b) soil moisture content is adjusted to about 60% of saturation; (c) the plastic crispers are then covered to prevent moisture loss due to evaporation; (d) tests are placed at a temperature of $13^{\circ}C$. for a period of 3-8 days; (e) lids are then removed and the tests transferred to a $30^{\circ}C$. room for emergence; and (f) average emergence of normal seedlings is determined.

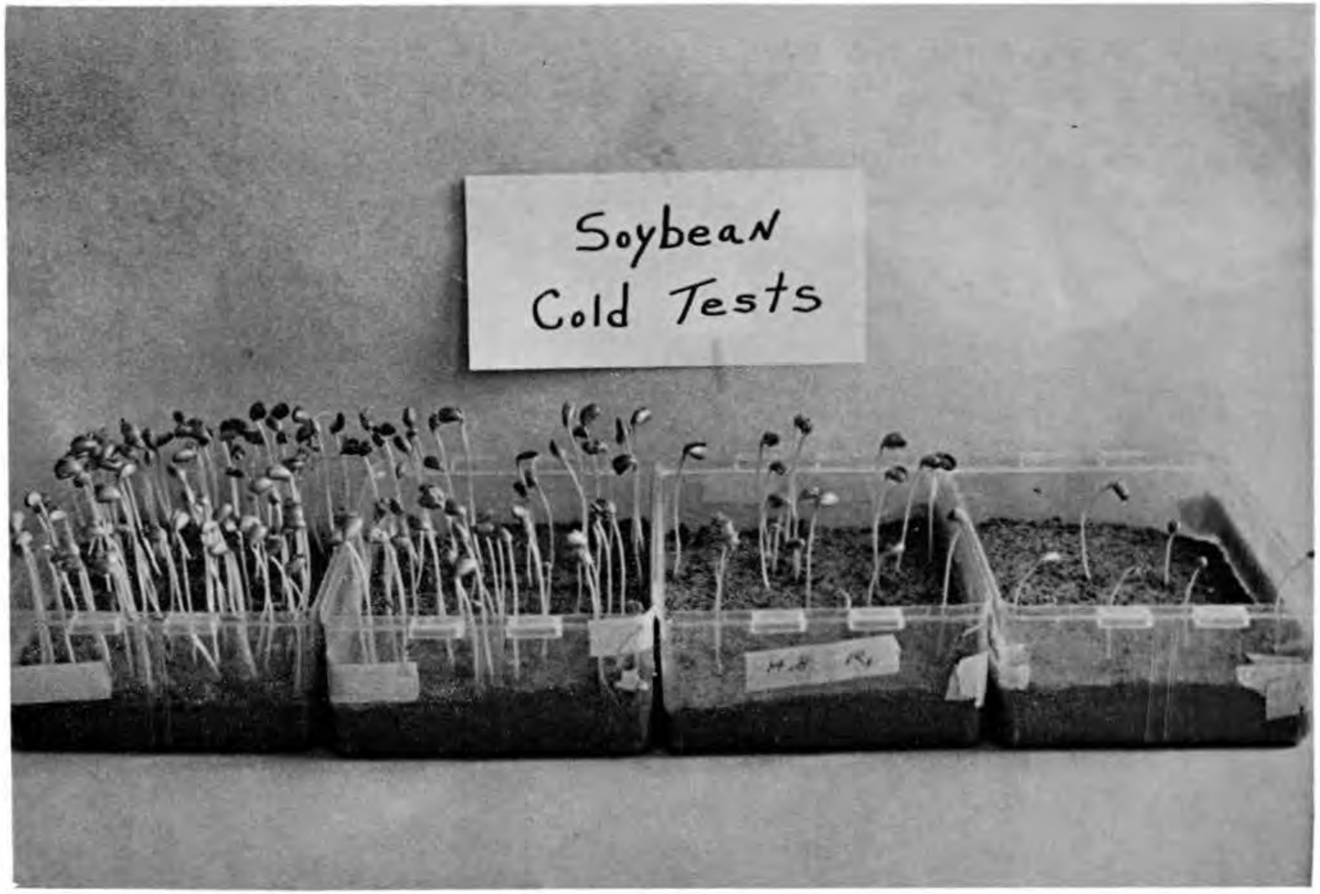

Figure 3. Cold test performance of four soybean lots germinating equally well in the standard germination test.

USES OF THE COLD TEST

In the past, the cold test has been used almost exclusively on corn seed lots. Some of these uses were to: (a) determine the quality of carry-over seed; (b) evaluate seed treatments; (c) test the effects of processing methods on the seed; (d) evaluate vigor in parent stocks; (e) compare the resistance of inbreds and single crosses; (f) evaluate the adequacy of storage conditions with respect to seed deterioration; and (g) determine the extent of frost injury and immaturity and its effect on seed vigor.

Recently, however, we have found that the cold test is applicable to many other crops and shows great potential for predicting storability (Tables 5 and 6) and field performance of various seed lots of the same kind.

There are several factors which affect cold test performance. Among these are: (a) degree of seed maturation; (b) age of seed; (c) amount of mechanical damage; (d) seed treatments; (e) genetic resistance; and (f) degree of organism infestation.

Some other factors make the cold test extremely hard to standardize among seed laboratories. These are:

1. Different soils used in cold tests. Soil used in various laboratories give different results due to variations in the amount of disease organisms present and differences in soil texture.

2. Different organisms in the soil exhibit various degrees of virulence.

3. Difference in cold test methods. Variations in soil moisture content and length of cold period and temperature cause varying results.

The lack of standardization, however, need not limit the usefulness of the cold test as a quality test. As long as each laboratory uses a consistent method, comparisons can be made among seed lots, varieties, etc.

Table 5. Comparison of standard germination and cold test emergence with germination of cottonseed following 18 weeks storage at 30°C. - 75% R.H.

Lot No.	Standard Germination %	Cold Test* %	30°C. - 75% 18 wks.
1	87.5	84.0	77.0
2	81.5	77.5	68.0
3	87.5	67.0	63.5
4	80.5	58.5	55.5
5	80.5	56.5	52.0

* 3 days at 13°C.

Table 6. Comparison of standard germination and cold test performance of corn seed stored for 18 months.

Months in Storage	30°C. - 55% R.H.	
	Standard Germination %	Cold Test %
0	95.5	88.6
2	99.0	89.4
4	95.0	84.0
6	94.0	63.4**
8	93.0	47.4**
10	91.5	20.7**
12	84.0	18.0**
14	62.0**	4.0**
16	29.0**	0.0**
18	9.5**	0.0**

** Denotes significance at 1% level of probability.

PACKAGING MATERIALS

Charles C. Baskin[1]

The materials available for packaging seed are almost as varied as the kinds of seed to be packaged. Most seedsmen are familiar with several different kinds of packaging materials and probably use more than one kind. Choosing a material for packaging can be a major decision for a seedsman. The proper package can mean the difference between a profit and a loss.

The type package you choose will be dependent upon several different factors: (1) the kind of seed to be packaged, (2) how the seed are to be handled, (3) the length of storage time, (4) the storage conditions, (5) are the seed to be shipped, (6) is so where to, and (7) what will be the conditions of shipment. These and other factors influence the selection of packaging materials.

CLASSIFICATION OF PACKAGING MATERIALS

Packaging materials may be classified several different ways. One method of classification is according to moisture resistance.

Materials which offer no resistance to moisture:

This classification consists of such materials as cotton, burlap and paper. Seed packaged in these materials will fluctuate in moisture content as the relative humidity of the air changes. Corn packaged in different type bags at 11.2% moisture and stored in a warehouse without any environmental control varied in moisture content as shown in Table 1, (1).

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Table 1. Moisture variation in corn stored in warehouse at 11.2% moisture (variety CF-78).

Bag Type	% Moisture by months in Storage					
	0	8	16	24	32	40
Polyethylene	11.2	11.1	11.1	10.7	10.5	12.9
Multiwall paper	11.2	11.5	12.2	11.6	12.8	13.2

Since these materials offer no resistance to moisture movement, seed that are to be exposed to high relative humidity conditions for even short periods of time would be expected to be more adversely affected than seed packaged in some type container that offers resistance to moisture movement.

An example of this is given in Table 2, (2).

Table 2. Corn stored at 85^{o}F. - 85% Relative Humidity Packaged at 8.5% Moisture (Variety CF-50).

Bag Type	Test	Months in Storage						
		0	2	4	8	12	16	18
Polyethylene	Std. Germ.	99	98	99	99	98	96	81
	Moisture	8.5	8.6	9.1	9.8	10.6	12.0	11.2
Multiwall paper	Std. Germ.	99	30	1	--	--	--	--
	Moisture	8.5	16.7	15.1		--	--	--
Cloth	Std. Germ.	99	46	2	--	--	--	--
	Moisture	8.5	16.0	17.6	--	--	--	--

On the other hand if seed must be packaged at a slightly higher moisture content than is desirable and are to be stored under dry conditions, these type materials will allow seed to lose moisture. The seed will equilibrate with the storage atmosphere and storability may be increased by this loss of moisture.

Therefore, if seed are to be stored under conditions of low relative humidity or packaged for short periods of time, packaging materials which offer little or no resistance to moisture may be adequate.

Materials which offer slight resistance to moisture:

A second group of packaging materials are those that offer some resistance to moisture movement. Examples of these are metal foils and paper, plastics, asphalt treated paper, plastic coated paper and various combinations of these materials. These materials do not completely inhibit moisture movement, but they restrict moisture movement. Since moisture movement is restricted seed moisture content is more critical when using packaging material of this type than when using packaging materials previously discussed. An example is given in Table 3, (1).

Table 3. Germination and Moisture Content of Soybeans Packaged in Different Materials at Different Seed Moisture Contents in Warehouse Storage.

		Months in Storage					
Bag Type	Test	0	8	16	24	32	40
Polyethylene	% Germ.	97	98	98	94	98	93
	% Moist.	9.0	9.0	9.5	9.4	9.5	9.3
	% Germ.	94	91	91	60	25	20
	% Moist.	11.2	11.1	11.8	11.5	13.8	13.3
Multiwall paper	% Germ.	97	98	96	93	98	95
	% Moist.	9.0	9.4	10.0	9.6	10.5	10.5
	% Germ.	94	95	92	92	90	63
	% Moist.	11.2	11.0	11.6	11.1	10.9	12.1

If seed are to be subjected to adverse conditions during transit or while they are in storage, containers which restrict moisture movement can be valuable in preserving germination and seed quality as shown in Table 2. This type container can be very effective in transoceanic shipment of seed or when shipping seed into tropical areas (2). Studies conducted by the Seed Technology Laboratory show that peanuts shipped to Thailand germinated 86.0% prior to shipment. Seed packaged in cloth bags germinated 33.0% on arrival while those in 10 mil polyethylene germinated 81.0% on arrival. The period of shipment covered four months.

Onion seed shipped to the Philippines germinated 94.0% prior to shipment. Seed packaged in cloth bags germinated 46.0% on arrival, while seed packaged in multiwall paper bags with a laminated plastic liner germinated 89.5% on arrival. The time in shipment was four months.

The benefits of using containers which restrict moisture movement are much more pronounced when packaging seed which do not store well, such as onion and peanuts as well as seed such as corn which stores quite well.

Materials which completely retard moisture movement:

The third group of packaging materials are those which completely retard moisture movement such as metal, glass or plastic coated, heavy cardboard containers. These materials are usually expensive and not always as practical as some of the previously mentioned materials. Very similar results are obtained from packaging seed in moisture resistant materials and moisture proof materials. For example onion seed packaged in metal cans and in multiwall bags with laminated plastic liners germinated equally well after 16 months storage in the Philippines (2).

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FUNDAMENTALS OF SEED DRYING

Bowen Campbell 1/

As all of you know, I am sure, the artificial drying of seed is a necessity in many cases and is a worth while operation in a good many other cases. In discussing the fundamentals of seed drying, I will skip most of the theory of drying as I am sure this could be better discussed by the professors and scientists at Mississippi State University. Suffice it to say that in an air dryer, whether natural air or heated air is used, the rule of thumb is that it takes about 1,000 BTU to evaporate a pound of moisture. There is no way to get around this basic drying fact. Varied and intricate designs of driers have been devised with no appreciable benefits. Infra-red radiation, high frequency radiation, vacuum and freeze drying have been tried but it requires heat energy to evaporate the moisture. Therefore, the dryer design should be made as simple and straight forward as possible.

The air in a heated air dryer has two functions; one of which is to supply this 1,000 BTU of heat for evaporating the moisture and the other is a vehicle for transporting the moisture away from the seed being dried and exhausting it into the atmosphere. Even in natural air drying this 1,000 BTU per pound of moisture evaporated is supplied by the air. In picking up the moisture from the seed the air is actually cooled in dry bulb temperature down to near the dew point and is exhausted from the drying bin a few degrees cooler than the temperature at which it entered the bin.

For any variety of seed or grain there is an equilibrium between moisture content and relative humidity of surrounding air. See Figure #1. For 12% Corn this is about 55% relative humidity. Heated air dryers speed up the drying over natural air drying because the relative humidity of the air is reduced below this equilibrium point by raising the temperature. The lower the relative humidity of the drying air the greater the difference from the equilibrium relative humidity and the faster the drying.

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ADSORBED MOISTURE IN EQUILIBRIUM WITH AIR OF VARIOUS HUMIDITIES AT ROOM TEMPERATURE (APPROXIMATELY 77F)

	Moisture content (wet basis), in percent							Authority
Relative humidity (percent)	15	30	45	60	75	90	100	
Barley	6.0	8.4	10.0	12.1	14.4	19.5	26.8	C&F
Buckwheat	6.7	9.1	10.8	12.7	15.0	19.1	24.5	C&F
Corn, shelled, YD	6.4	8.4	10.5	12.9	14.8	19.1	23.8	C&F
Corn, shelled, WD	6.6	8.4	10.4	12.9	14.7	18.9	24.6	C&F
Corn, shelled, Pop	6.8	8.5	9.8	12.2	13.6	18.3	23.0	C&F
Flaxseed	4.4	5.6	6.3	7.9	10.0	15.2	21.4	C&F
Oats	5.7	8.0	9.6	11.8	13.8	18.5	24.1	C&F
Rice, rough	5.6	7.9	9.8	11.8	14.0	17.6	-	K&A
Rice, undermilled	5.9	8.6	10.7	12.8	14.6	18.4	-	K&A
Rice, polished	6.6	9.2	11.3	13.4	15.6	18.8	-	K&A
Rye	7.0	8.7	10.5	12.2	14.8	20.6	26.7	C&F
Sorghum	6.4	8.6	10.5	12.0	15.2	18.8	21.9	C,R&F
Soybeans	-	6.2	7.4	9.7	13.2	-	-	R&G
Wheat, white	6.7	8.6	9.9	11.8	15.0	19.7	26.3	C&F
Wheat, Durum	6.6	8.5	10.0	11.5	14.1	19.3	26.6	C&F
Wheat, soft red winter	6.3	8.6	10.6	11.9	14.6	19.7	25.6	C&F
Wheat, hard red winter	6.4	8.5	10.5	12.5	14.6	20.1	25.3	C&F
Wheat, hard red spring	6.8	8.5	10.1	11.8	14.8	19.7	25.0	C&F

(C&F) Coleman & Fellows. Hygroscopic moisture in cereal grains. Cereal Chem., vol.II, pp.275-287, Sept. 1925. (Moisture content determined by water-oven method.)

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(R&G) Ramstad & Geddes. The respiration and storage behavior of soybeans. Univ. Minn. Tech. Bul. 156, June, 1942. (Moisture determined by vacuum-oven method.)

(K&A) Karen & Adams. Hygroscopic equilibrium of rice and rice fractions. Cereal Chem., vol. XXVI, pp. 1-12, Jan., 1949. (Moisture determined by forced-draft air-oven method.)

Figure #1

Seed is especially hard to dry because the drying temperature is limited to 110°F. or there about for fear of damage to the germination and therefore, the relative humidity of the drying air cannot be reduced as low as it is in high temperature commercial grain dryers. All of you who have seed dryers have experienced the slow drying on hot humid afternoons. It can be shown on a psychometric chart that the humidity of the heated air may be as high as 50% after being heated to 110°F, which will only, after a long time, dry seed down to the 12% moisture content required. Some drying, of course, will be done in the bins where the moisture content of the seed is relatively high because the relative humidity at equilibrium is possibly 90 or 95%, if the moisture of the seed is as high as 25 or 30%.

I would like to discuss hybrid seed corn drying as that is the field in which I have had the most experience, but the principles involved apply to other kinds of seed. Seed corn is dried on the ear for reasons you know better than I. A few growers are shelling before drying but tests are indicating that the vigor and viability of the seed corn is adversely effected. The design of hybrid seed corn drying plants is not an exact science from an engineering point of view. Certainly there are many known facts and formulas to be applied, but there remains a considerable quantity of practical design information that is constantly changing. Dryer design can be said to be more of an art than a science. In 35 years of working with the seed corn industry I have been in the fortunate position to grow up with and observe the evolutionary changes. As a result, drying plant and equipment design today is very different from the early plants, and very much better, I might add. Some of you remember the drying equipment used 30 or 35 years ago when gas as a fuel was not often available and practically every drying plant used fuel oil. The burners were very crude and hard to adjust, the temperature was regulated manually by turning the fire a little higher or a little lower and there were practically no safety controls except a high temperature limit. The burners were manually lighted with a torch. Today most dryers burn gas with electric ignition, automatic temperature control and safety controls that may go to the other extreme of being a little complicated causing nuisance shut downs.

The fans have evolved from the original squirrel cage blowers that considerably overloaded the motors easily under some conditions of low static pressure. They were lacking in ability to build up the static pressures that we use today.

The bin construction has certainly improved to permanent type, fire proof, air tight, construction with self cleaning floors and more or less self leveling in filling. The material handling equipment for filling and emptying the bins works almost to perfection now. I know of one plant where the capacity of about 10,000 bushels per 24 hours in which two women handle the filling and emptying of the drying bins.

Some of the variables that defy analysis for design purposes are the wide ranges of temperature and humidity of the air during the drying season affecting the drying rate, expecially since the temperature rise is rather small under some conditions such as warm afternoons and high humidities. There is a wide variation in the moisture content of the corn put into the drying bins, some as high as 40% early in the season down to 25% or lower towards the finish.

There is a wide variation in the number of bins that are filled at any one time which is influenced by the weather and the ability of management to make the best use of drying bins available. It is quite customary as soon as it is decided to pick seed corn that all of the bins in the building are filled with very high moisture corn and the equipment has to be capable of drying it before mold and bacteria growth cause damage. This requires high capacity equipment and the design must be a compromise to give operating efficiency during normal operation of the drying plant. On the other side of the operation we have seen instances during the drying season when the bins become completely empty due to weather that prevents picking of the seed corn.

The air resistance through a bin of corn varies considerably with a type of corn. The high percentage of single cross hybrid seed corn being produced today packs into the bin rather tightly making it necessary to provide a higher static pressure than was the case a few years ago. The single crosses, in addition, are usually picked at high moisture content to prevent field losses on account of the high value of this type seed corn and this adds to the drying problem.

The tendency, therefore, in drying plant design is to go to larger motors, higher static pressures and high air volumes for any given bin. There are also lesser variables such as the fact that some hybrids have larger cobs that hold moisture and you can probably think of a half dozen other variables.

A seed drying plant can be designed with any number of bins depending upon the number of different varieties that it will handle, the ease of filling and emptying and so forth, but it should have enough bins so that an orderly rotation of the use of the bins can be accomplished.

Drying plants are usually designed so that each bin will dry in about 72 hours. Using the data shown in Figure #2, a chart should be prepared indicating how deep to put the seed corn in the bins for the various original moisture contents so that there will be about the same amount of moisture to evaporate from that bin whether it goes in originally at 35% or higher, or, later in the season goes in 25% or lower. The manager of the drying operation can then anticipate that the bin will dry in 72 hours and rotate the use of them accordingly. This drying time for a bin seems to be desired by the industry as it is well within the time that will get the seed corn dry before mold and bacteria action has begun to cause any damage to the germination. This also works out to be the most economical use of the drying bins and drying equipment.

No seed drying plant can be designed for 100% operating efficiency. Heated air drying plants instead of requiring a 1000 BTU/lb. of moisture evaporated may require 2000 or 3000 or more BTU/lb. of moisture evaporated due to the fact the heated air that supplies the heat for evaporating the moisture and carrying it away carries with it, when exhausted from the drying bins, a considerable amount of heat. The efficiency of the drying plant design has to be a compromise, taking into consideration the original investment in the drying bin building itself and the relation of the air handling and heating equipment with the operating costs for fuel and power. It is a pretty complex problem to arrive at the best solution, taking into the account the wide range in different type of building cost, power and fuel costs.

Figure #2

Approximate amount of water in ear corn, when harvested at different percentages of moisture content of the kernels

Kernel moisture content (percent)	Amount of water in a bushel of ear corn		
	In kernels (pounds)	In cobs (pounds)	Total (pounds)
35	25.5	12.4	37.9
30	20.3	9.9	30.2
28	18.4	8.8	27.2
26	16.6	7.8	24.4
24	14.9	6.7	21.6
22	13.3	5.5	18.8
20	11.8	4.4	16.2
18	10.4	3.2	13.6
16	9.0	2.1	11.1
14	7.7	1.4	9.1
12	6.5	0.9	7.4
10	5.3	0.5	5.8

*A bushel of ear corn is defined here as the quantity that will yield 56 pounds of shelled corn at 15.5 percent moisture.

Drying of seed corn is being done in crib type structures, round steel bins with perforated floors, multiple round bins, steel or concrete stave/silo types or drying bin structures of frame construction, pole construction, prefabricated steel, masonry construction, poured concrete structures and tilt up concrete structures. Typically drying costs run about as follows:

Depreciation and interest on the drying bins	14¢/bu.
Power	2
Fuel, natural gas	4
Labor	7
	27¢/bu.

The cheaper structures are probably not economical because of higher depreciation rates, higher fire insurance rates, and less operating efficiencies. However, less capital investment is sometimes a necessity and any of the above types of construction can be used in the design of an effective seed drying plant. The best type of construction and design of your plant should be worked out with your consulting engineer and contractor.

There are two basic designs of drying plants consisting of continuous flow dryers or batch dryers. Seed drying has not in general worked out well with a continuous flow dryer due to the necessity of keeping individual varieties and batches separate. At one time it seemed the sorghum seed industry could use the continuous flow dryer to good advantage but the trend is now to batch type dryers very similar to the design of the hybrid seed corn plants. The drying bins are built with the same type of loping floors, filling and emptying conveyors and heated air drying equipment. The sorghum seed is put in the bins to a uniform depth of about 30 inches. If a continuous flow dryer is advisable in some instances for seed it should be designed for counter flow.

There are two further types of dryers, namely; counter flow and con-current or parallel flow. The con-current or parallel flow is being tried in commercial dryers sacrificing operating efficiency for high capacity using high drying temperatures, but our study of it so far does not indicate it would be the huge success its sponsors hoped, and we feel sure it has no application at all in seed drying.

Counter flow means the product, seed to be dried, flows in the opposite direction from the drying medium, heated air, giving the highest efficiency. This means that the entering heated air comes first in contact with the driest seed and as the air progresses through the dryer it picks up moisture and loses temperature. It contacts higher and higher moisture content seed until, on being exhausted, it is passing over the coolest and the highest moisture seed just being brought in from the field that needs to be warmed to start the drying process and has surface moisture present which can be quickly and easily evaporated. The air is then exhausted at a relatively high humidity and low temperature, resulting in the highest efficiency.

Since continuous flow dryers are not suitable for most seed drying operations, an approximation of this counter flow principle can be accomplished by using a two-pass system in which the high temperature drying air is first directed through the bins containing the more nearly dry corn. This then picks up only a small amount of the moisture it is capable of holding and loses only a small portion of its heat. It is then transferred and exhausted through one of the more nearly freshly filled bins that needs to be warmed up and surface moisture is available for being evaporated. This makes a little more complicated drying procedure but is well worth it, as in our opinion it adds about 25% to the drying capacity of a given size drying plant and reduces the fuel cost considerably, although it adds something to the power cost. Below are some illustrations of this type of design.

This two-pass design also has an advantage in that there is some added protection to the germination of the seed. Seed is more susceptable to damage from high drying air temperatures when the moisture content is high, and less susceptable to this damage when the moisture content is low. Therefore, only the nearly dried seed is subject to a possible 110 or 115 degree drying air temperature and the high moisture seed is exposed to drying air at 80 or 90 degrees or less.

Another common design of seed drying plants is a single-pass arrangement with the capability of reversing the air direction through the various bins occasionally to obtain uniform drying. In the single-pass system, you can realize that when the bin is first filled, the drying air first comes through the bin and is exhausted, nearly saturated, but towards the end of the drying cycle the air is being exhausted without having picked up very much moisture and not having given up much of its heat so that it has considerable drying potential being wasted. This method of drying has only about 80% of the efficiency and capacity of the two-pass system.

A third type of drying plant design is a single-pass system with no provision for reversing air direction, and the drying of the seed is probably several percentage points too low where the air enters the bin, usually the bottom of the bin, and several percentage points too high where the air leaves the bin. The operator then depends on the blending of the seed to equalize the moisture content. There problably is some damage to the rough ears in shelling and we estimate that such a plant is about 75% of the capacity and efficiency of the two-pass system.

Below are some photographs of seed drying plants. The bins are of different types of construction and the drying equipment in some cases is portable equipment on skids which has the advantage that the unit is factory run and tested and comes ready simply to put in place and connect up the power and fuel lines.

The stationary drying equipment is quite often built into a steel building and some of the plants have drying equipment at each end. This is due to the fact that it is not practical to go above a certain motor, blower or burner size. In fact, costs start to rise disproportionately and it is cheaper and more flexible to use two units.

Drawings for building drying bins to get the best possible drying results are presented at the end of this article. These drawings are worked out on a basis of good balance between the investment in the bins, the investment in the drying equipment and the operating efficiency.

The first drawing is of a small size drying plant using the two-pass system with a small portable drying unit. This portable drying unit, and in a good many of the stationary drying equipment buildings, is elevated enough so that the fresh air can be brought up thru the unit from the bottom. The advantage of this arrangement is that the wind effect on the distribution of fresh air over the burner has very little effect; therefore, a very even and uniform drying air temperature is obtained. The screens on the fresh intake are not being continually plugged with husks and other foreign material. In addition the line burner can be spread out over the area of the fresh air intake and the heat from the burner has a good chance of getting well mixed with the air in traveling from the burner to the blower intakes and then is further mixed in passing through the blower. A good uniform temperature is essential for good safe seed drying.

The second drawing shows another small two-pass system used for foundation seed and therefore, has smaller bins and more of them. It illustrates a sloping roof with enclosed top conveyor.

Drawings three and four illustrate another two-pass drying system of eight bins, and you will notice these drawings are more in detail as it was structurally designed. They are good illustrations of a frame building. Buildings built of something more permanent and fireproof are preferable but, with careful design, and a few precautions a frame building can be entirely practical.

The fifth drawing illustrates a single-pass drying system, but in which the air can be reversed to get even drying, and also illustrates the use of round bins. The lesser efficiency of a single-pass system is somewhat offset by the ability to reverse the direction and the fact that the corn can be put in these bins 14" deep.

The sixth drawing illustrates round steel bins simply blowing up through and is probably one of the cheapest ways from first cost standpoint of building a drying plant.

The seventh and eighth drawings illustrate another method of drying that may have some merit and is being used more frequently. This illustrates a two-pass pull through system in which the air is pulled into the drying plant at the ground level past the burners where it is heated and then is pulled through the bins in the rotation of sequence as desired and exhausted by the blowers finally to the atmosphere. This building was originally designed to make it possible to cool the corn before it is taken from the bin for shelling. Two of the seed drying companies who have had this type of system have duplicated the drying system after a few years use of the first one constructed. They indicate that they are getting exceptional drying capacities and efficiency, which is a little hard to explain. The most likely explanation is the fact that any leakage in building construction, and the doors in particular, is inward. Leakage air, which is normally lost completely in the normal drying plant in the pull through plant, mixes with the drying air and has some moisture carrying capacity which is useful. It is surprising how much drying capacity and efficiency is lost due to leaky building construction and poor fitting doors in drying plants. Since the leakage cannot be observed, the dryer operators are not aware of a rather significant loss.

The ninth drawing might be applicable to a good many seed processors of small seed who have many small batches. It has worked well for several hybrid seed corn growers for their parent stock and inbred drying. This might be good for all types of small seeds. The seed is put into boxes with perforated floors to an appropriate depth and these are moved by means of a fork truck and placed two or three boxes deep on each side of a central air duct. The air is blown only one way up through the drying boxes but the depth is rather shallow with the air volume high since high efficiency is not too much of a consideration. The fork trucks can be provided with a device for tipping and emptying the boxes so that the handling of this seed is rather simple with minimum amount of labor.

There is some interest in drying seed to extremely low moisture content for carry over a year or longer. Shelf life and this is a difficult problem. For instance, on a 50°F. day with 50% relative humidity, if the drying air is heated to 110°F., the relative humidity is reduced only to about 15% which leaves no spread from the approximate 15% equilibrium relative humidity for 6% moisture seed for bringing the moisture content of the seed down. If the seed can be dried down at harvest to a reasonable low moisture content, such as 10 or 12% for storage, it can be dried on down to a very low moisture percentage at some later time when the outdoor temperature is 32°F. or below, because then, by heating the air to 110°F., the relative humidity can be reduced to 7 or 8%. There is a spread between this and the 15% approximate equilibrium relative humidity for 6% moisture content seed.

Another alternative is to dehumidify the air either chemically or with a reverse refrigeration cycle, and then the complete drying to a very low moisture percentage can be done at harvest in drying bins. Another alternative is to dry the seed in storage over a long period of time by keeping it in a room in which the atmosphere in the room is dehumidified.

We might discuss for a minute the various fuels and their relative cost. Natural gas is ordinarily the cheapest and best fuel. LP gas may require vaporizing of the liquid from the tank and is probably the most expensive fuel. Fuel oil is in between, and with the proper fuel oil burning equipment, causes very little difficulty. To get a rough check of the comparative fuel cost, simply figure the cost of a therm which is 100,000 BTU and in the average seed plant location, natural gas can be purchased for 5 or 6¢ a therm, fuel oil for 9 or 10¢ a therm, and LP gas for 12 or 13¢ a therm.

The burner controls that you need for seed drying equipment consists of the following and I'll try to list them in the order of their importance:

1. An air flow air pressure switch that will assure that the blower is delivering somewhere near its full air volume before the burner can be operated, or if the volume should fail during operation, the burner will automatically shut off. This is the most important safety control on the burner. Even with the gas supply valve wide open and unlighted there is so much dilution of the gas with the air being handled that it does not form an explosive mixture. Those of you who have drying equipment know that with the blower running you can open the gas valve and some minutes later ignite the gas burner with a nice smooth ignition of the burner without any puff or trouble.

2. The burner should be wired in electrically so that the burner cannot possibly operate unless the blower motor is energized.

3. An operating high temperature limit control set a few degrees higher than the normal operating temperature. It will shut the burner down. The burner in all cases should shut down and remain off till manually relighted.

4. The automatic temperature regulation should modulate the burner with a good steady size to maintain the drying temperature without the fluctuations, hunting, and surging that is sometimes observed with what is expected to be a modulating temperature control.

5. A flame sensing device that will shut down the burner in case of flame failures does not need to be quick acting, complicated or expensive electronic control that is so essential on burners in boilers and confined combustion spaces. A shut down of the burner in a matter of 20 or 30 seconds even after the flame has gone out presents no hazard.

6. An alarm system using multiple 165°F. thermostats to detect over heating from any cause and especially from external source of fires. This control should not only shut down the burner but shut off the blower and sound an alarm. It is intended to detect fires from sources other than the burner. It should shut off the blower to keep from fanning the fire to greater intensity. These alarm thermostats are relatively inexpensive and can be located at many points throughout the drying plant.

DRAWING INDEX

Drawing #1

A small two-pass drying plant

Drawing #2

A drying plant with many small bins for small lots of many varieties.

Drawing #3

Some details of a frame construction drying plant.

Drawing #4

Details of frame construction showing removable perforated floors to permit storage in bins after drying.

Drawing #5

Single pass drying capable of air direction reversal using two silos and portable dryer.

Drawing #6

Single pass drying system, one direction only using round steel bins but designed to hold shelled corn storage after drying.

Drawing #7

A pole building type drying bins with pull through, two pass drying system.

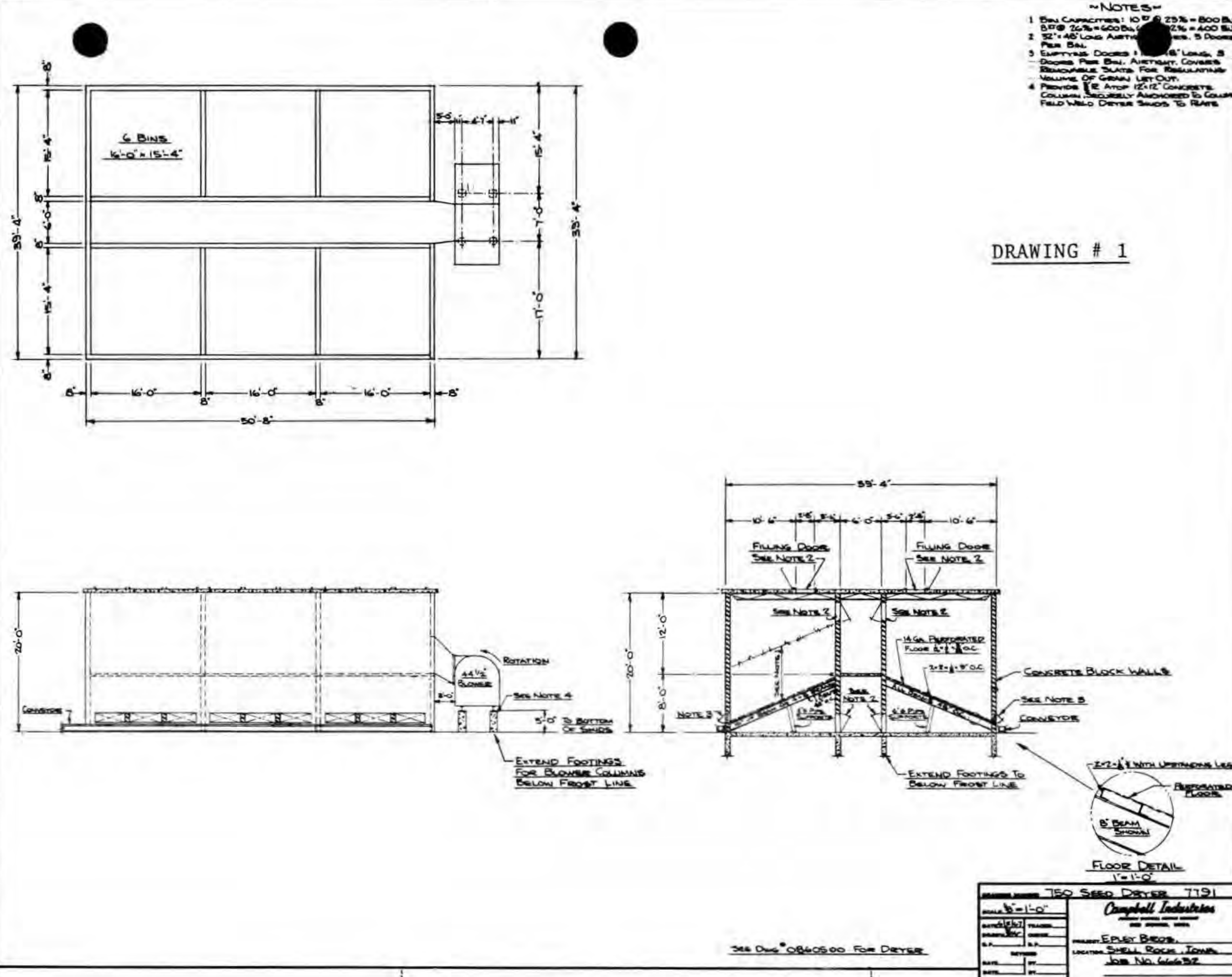
Drawing #8

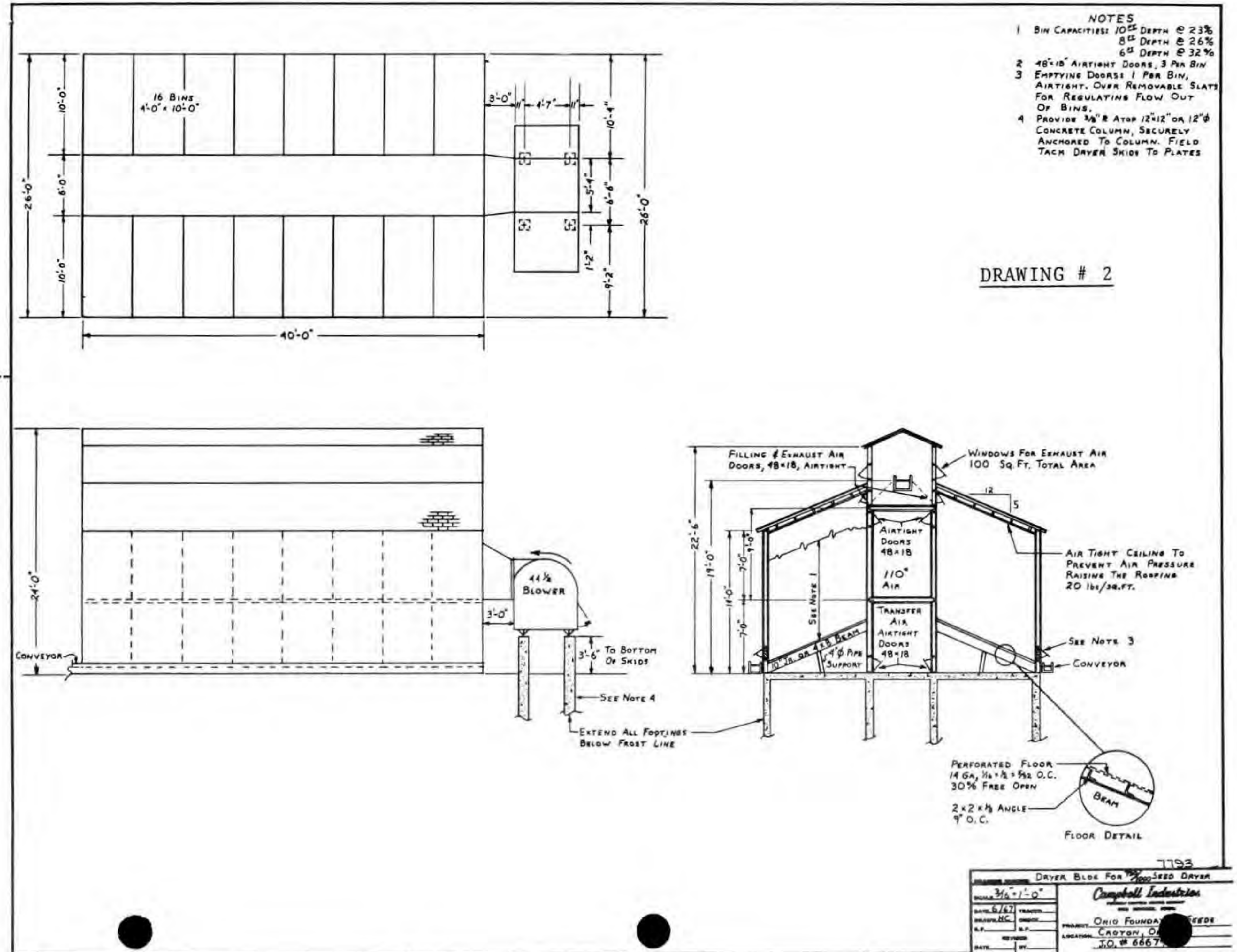
A pole building, pull through system.

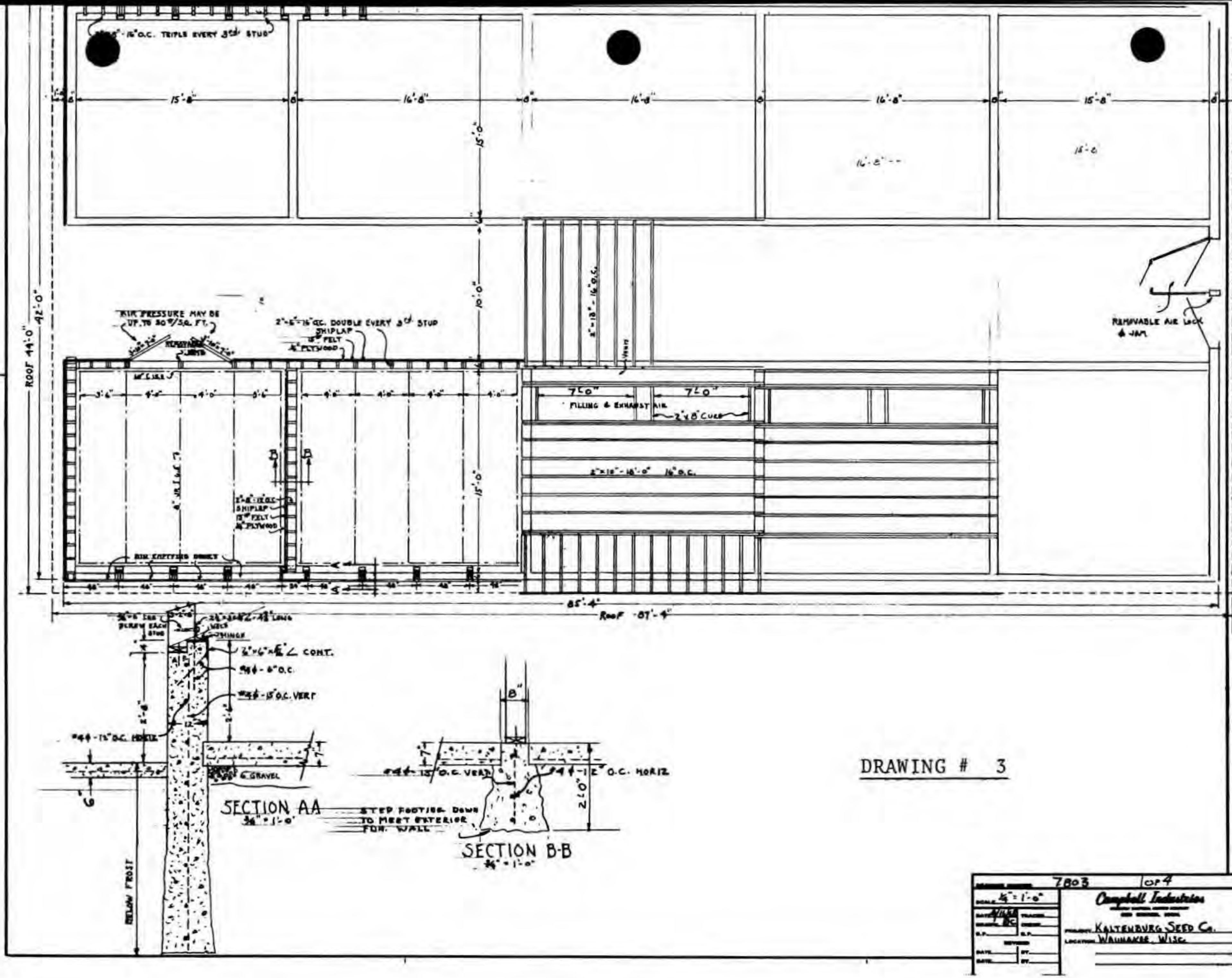
Drawing #9

A dryer using boxes handled by a fork lift for small lots and suitable for small seeds as well as ear corn.

DRAWING # 1

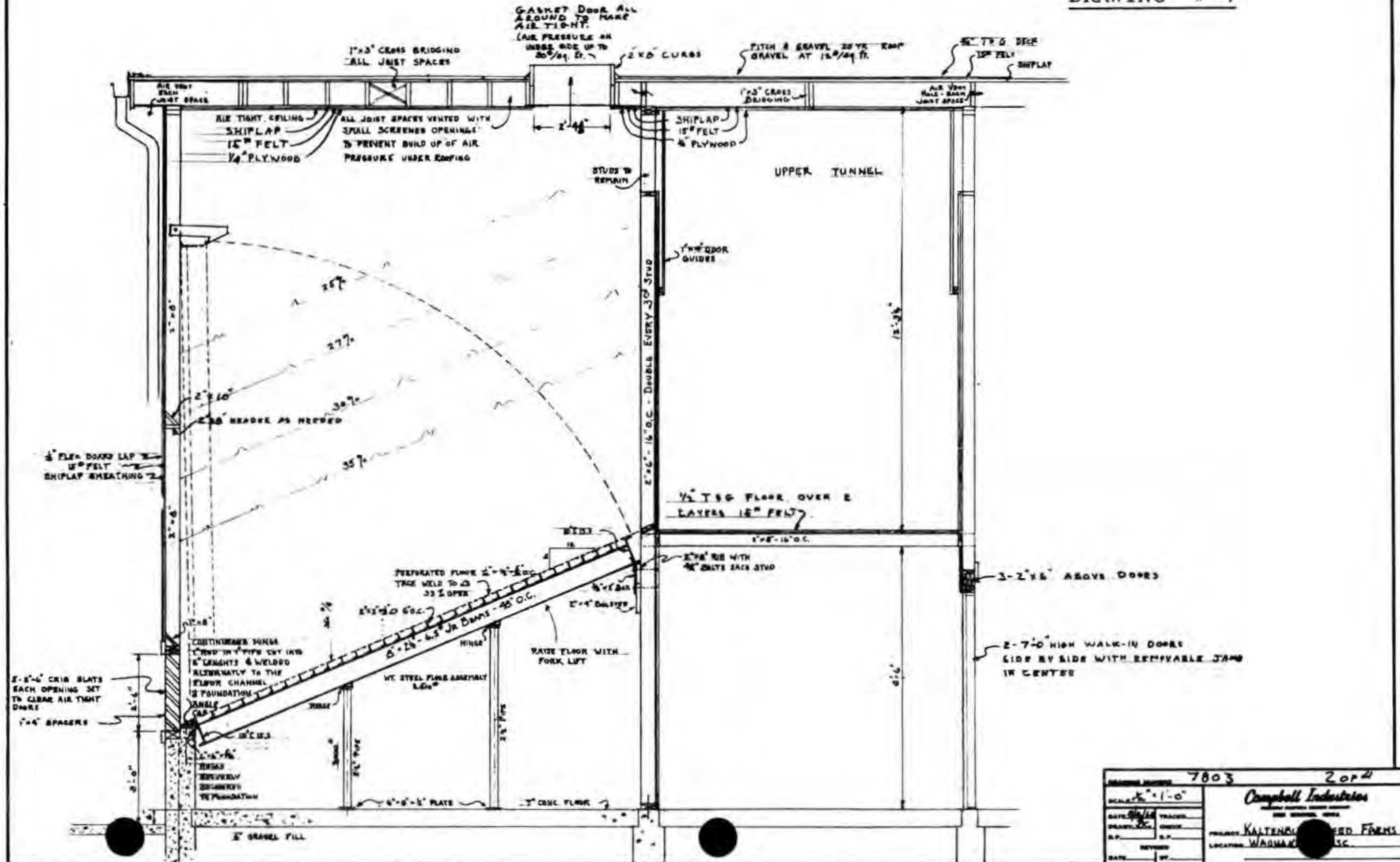

~NOTES~
6 BINS
16'-0" x 15'-4"
50'-8"
39'-4"
35'-4"
FILLING DOOR
SEE NOTE 2
CONCRETE BLOCK WALLS
SEE NOTE 3
CONVEYOR
EXTEND FOOTINGS TO
BELOW FROST LINE
EXTEND FOOTINGS
FOR BLOWER COLUMNS
BELOW FROST LINE
ROTATION
SEE NOTE 4
FLOOR DETAIL
SEE DWG #0860500 FOR DRYER
750 SEED DRYER 7791
Campbell Industries
EPLEY BROS.
SHELL ROCK, IOWA
JOB NO. 66652


NOTES
1 Bin Capacities: 10 Ft Depth @ 23%
8 Ft Depth @ 26%
6 Ft Depth @ 32%
2 48"x18" Airtight Doors, 3 Per Bin
3 Emptying Doors: 1 Per Bin, Airtight. Over Removable Slats For Regulating Flow Out Of Bins.
4 Provide 3/8" ℞ Atop 12"x12" or 12"ϕ Concrete Column, Securely Anchored To Column. Field Tack Dryer Skids To Plates
DRAWING # 2
16 Bins
4'-0" x 10'-0"
10'-0"
6'-0"
10'-0"
26'-0"
40'-0"
3'-0"
11"
4'-7"
11"
10'-4"
5'-4"
6'-6"
1'-2"
9'-2"
26'-0"
24'-0"
Conveyor
44 ½
Blower
3'-0"
3'-6" To Bottom Of Skids
See Note 4
Extend All Footings Below Frost Line
Filling & Exhaust Air Doors, 48x18, Airtight
Windows For Exhaust Air 100 Sq. Ft. Total Area
12
5
Airtight Doors 48x18
110" Air
Transfer Air Airtight Doors 48x18
See Note 1
4"ϕ Pipe Support
Air Tight Ceiling To Prevent Air Pressure Raising The Roofing 20 lbs/sq.ft.
See Note 3
Conveyor
22'-6"
19'-0"
14'-0"
9'-0"
7'-0"
7'-0"
Perforated Floor 14 Ga, 1/16 x ½ x 5/32 O.C. 30% Free Open
2 x 2 x ⅛ Angle 9" O.C.
Beam
Floor Detail
7793
Dryer Bldg For Seed Dryer
Campbell Industries
Scale 3/16" = 1'-0"
Date 6/67
Drawn HC
Project Ohio Foundation Seeds
Location Croton, O
J.O. # 6667

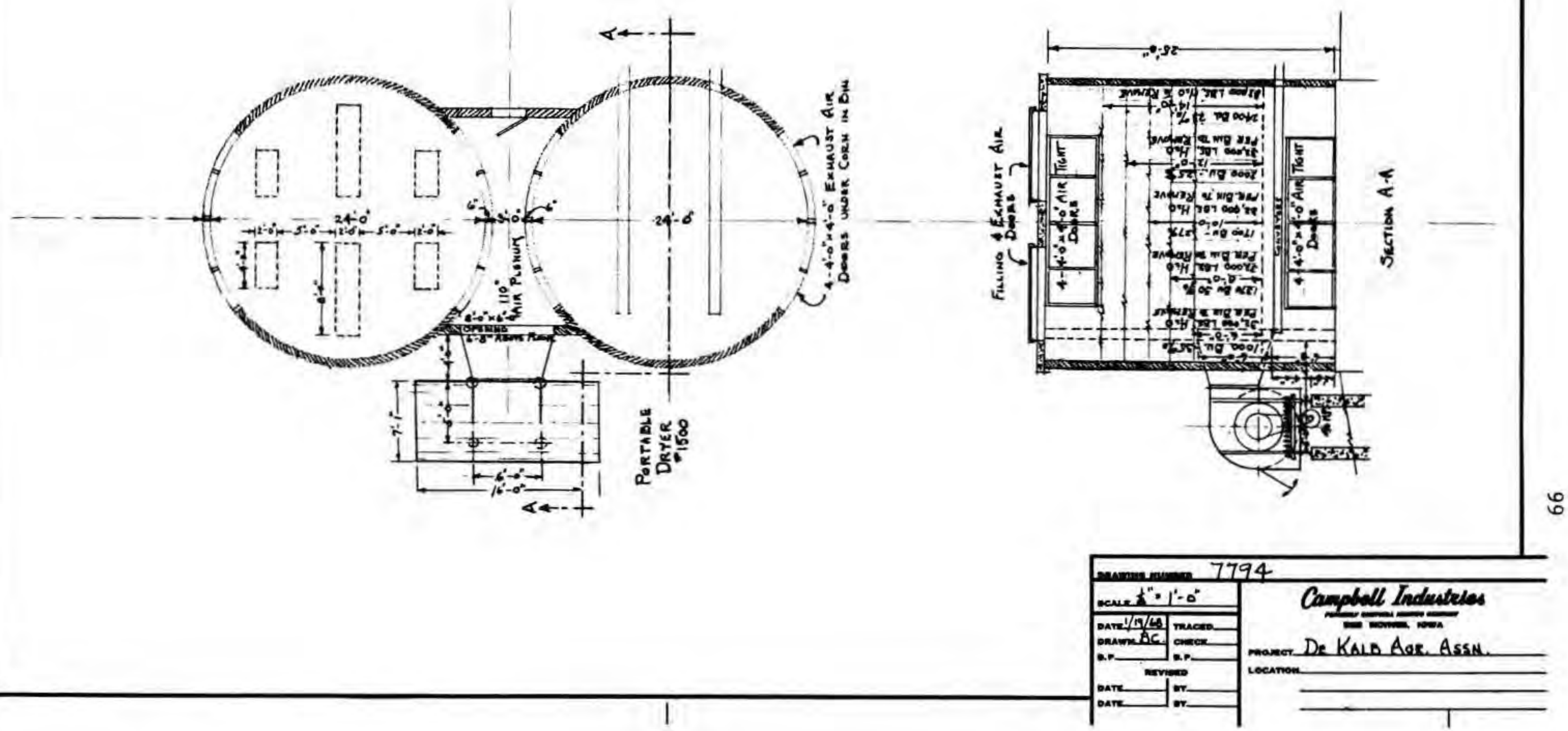

2"x6"-16"O.C. TRIPLE EVERY 3rd STUD
15'-8"
16'-8"
16'-8"
16'-8"
15'-8"
15'-0"
10'-0"
15'-0"
AIR PRESSURE MAY BE UP TO 30#/SQ. FT.
2"x6"-16"O.C. DOUBLE EVERY 3rd STUD
SHIPLAP
15# FELT
½" PLYWOOD
2"x18"-16"O.C.
REMOVABLE AIR LOCK & JAM
7'-0"
7'-0"
FILLING & EXHAUST AIR
2"x8" CURB
2"x10"-18'-0" 16"O.C.
AIR EMPTYING DUCTS
85'-4"
ROOF 87'-4"
ROOF 44'-0"
42'-0"
2"x6"x6" ∠ CONT.
#4Φ-6"O.C.
#4Φ-15"O.C. VERT
#4Φ-12"O.C. HORIZ
GRAVEL
SECTION AA
¾" = 1'-0"
BELOW FROST
STEP FOOTING DOWN TO MEET EXTERIOR FDN. WALL
#4Φ-15"O.C. VERT
#4Φ-12"O.C. HORIZ
2'-0"
8"
SECTION B-B
¾" = 1'-0"
7803
OF 4
Campbell Industries
KALTENBURG SEED CO.
WAUNAKEE, WISC.

DRAWING # 3

DRAWING # 4

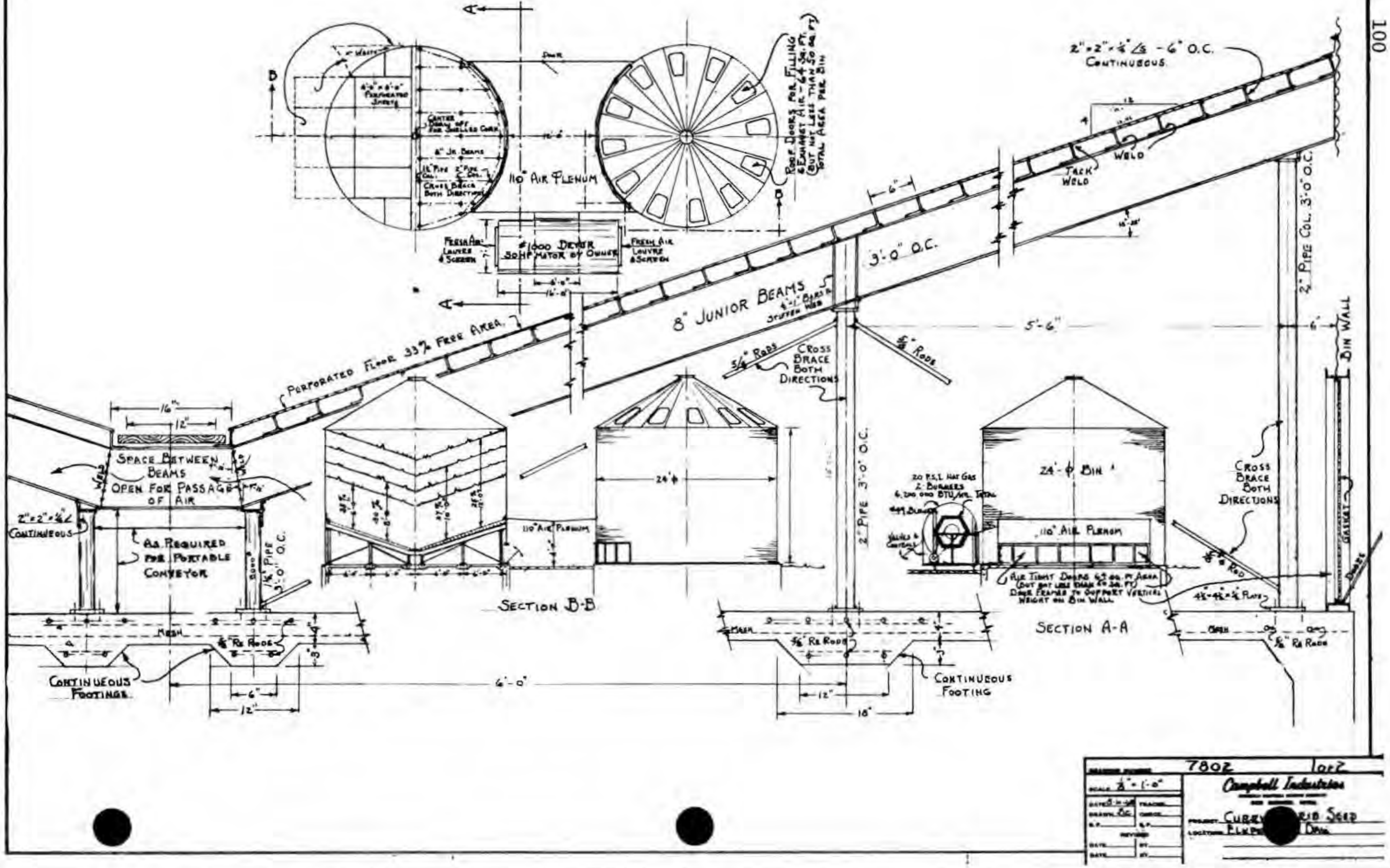

GASKET DOOR ALL AROUND TO MAKE AIR TIGHT.
(AIR PRESSURE ON INSIDE SIDE UP TO 30#/sq. ft.)
1"x3" CROSS BRIDGING ALL JOIST SPACES
2"x6" CURBS
PITCH & GRAVEL 20 YR. ROOF GRAVEL AT 12#/sq. ft.
15# FELT
SHIPLAP
AIR TIGHT CEILING
SHIPLAP
15# FELT
1/4" PLYWOOD
ALL JOIST SPACES VENTED WITH SMALL SCREENED OPENINGS TO PREVENT BUILD UP OF AIR PRESSURE UNDER ROOFING
1"x3" CROSS BRIDGING
SHIPLAP
15# FELT
PLYWOOD
STUDS TO REMAIN
UPPER TUNNEL
DOOR GUIDES
DOUBLE EVERY 3rd STUD
2"x8" HEADER AS NEEDED
SHIPLAP SHEATHING
1/2" T&G FLOOR OVER 2 LAYERS 15# FELT
3-2"x6" ABOVE DOORS
PERFORATED FLOOR
RAISE FLOOR WITH FORK LIFT
HINGE
CONTINUOUS HINGE
FOUNDATION
ANGLE CAP
1"x4" SPACERS
2-7'-0" HIGH WALK-IN DOORS SIDE BY SIDE WITH REMOVABLE JAMB IN CENTER
PLATE
CONC. FLOOR
GRAVEL FILL
7803
2 OF 4
Campbell Industries
KALTENB... FARMS
WAUWA... WISC.

DRAWING # 5

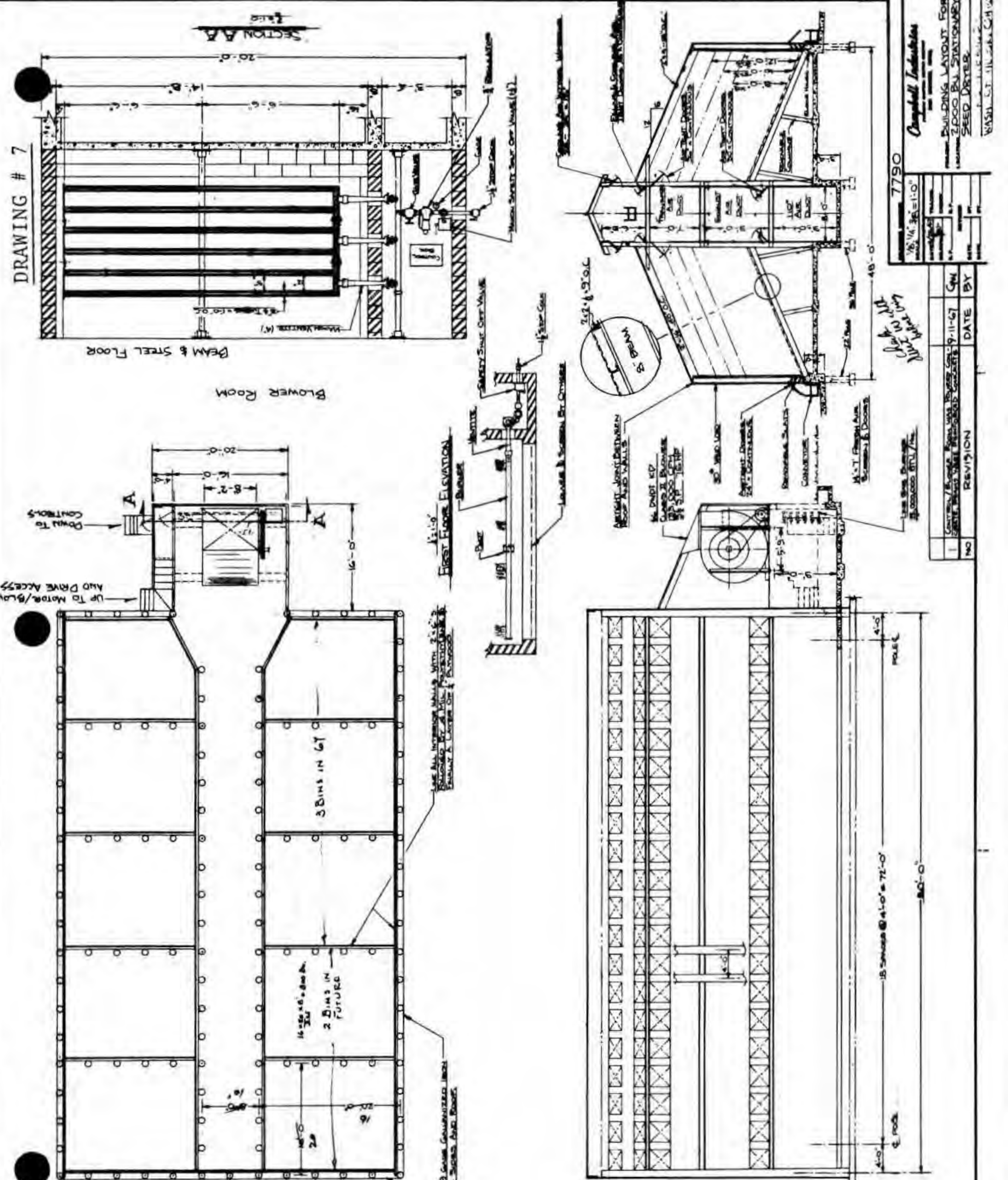


24'-0"
24'-0"
110° Air Plenum
4-4'-0"x4'-0" Exhaust Air Doors under Corn in Bin
Portable Dryer #1500
6'-0"
16'-0"
7'-1"
Filling & Exhaust Air Doors
4-4'-0"x4'-0" Air Tight Doors
Section A-A
25'-0"
Drawing Number 7794
Scale 1/8" = 1'-0"
Date 1/19/68
Drawn BC
Campbell Industries
Project De Kalb Agr. Assn.
Location

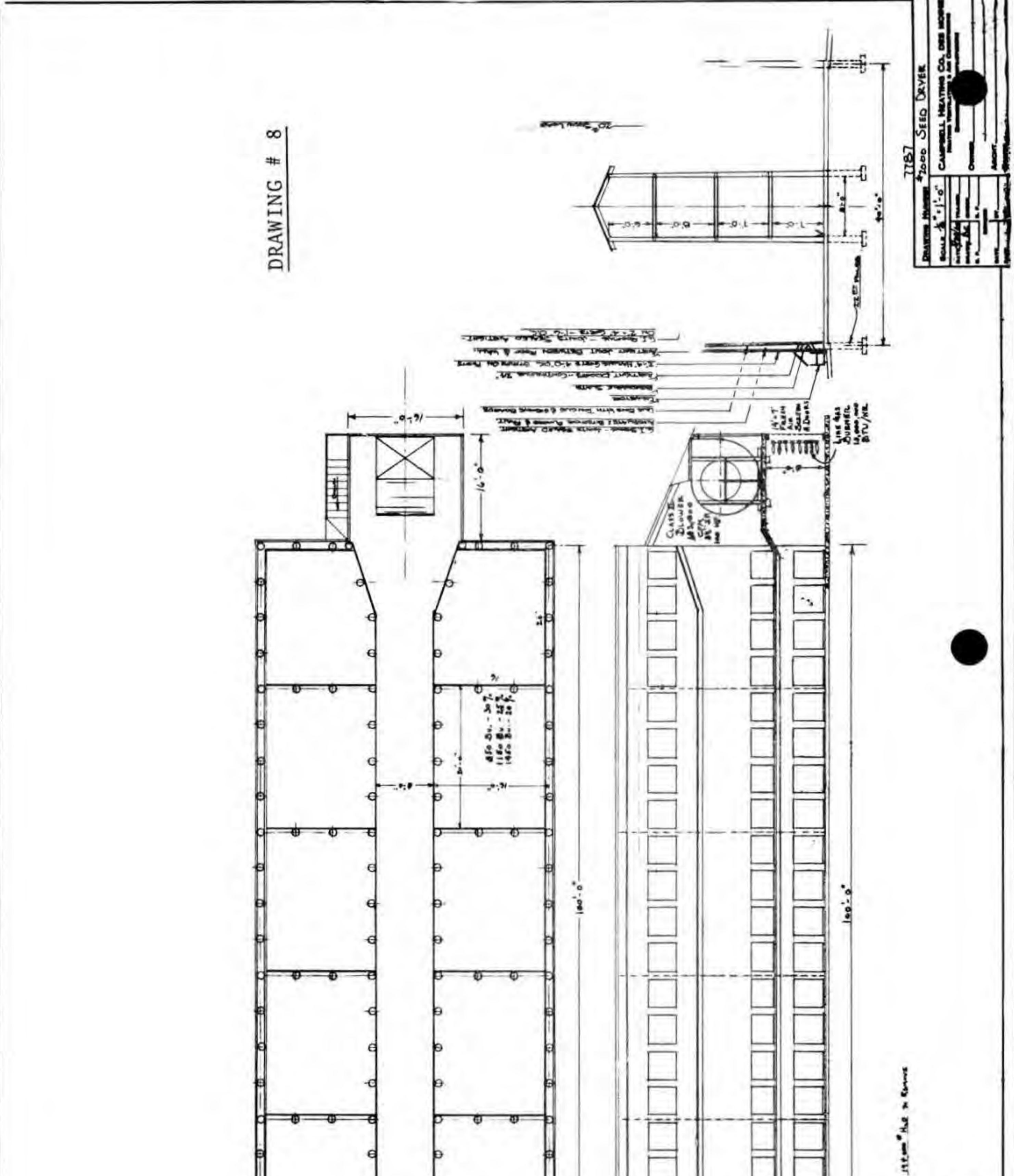
DRAWING #6


2"×2"×¼" ∠s - 6" O.C. CONTINUOUS
WELD
JACK WELD
3'-0" O.C.
8" JUNIOR BEAMS
PERFORATED FLOOR 33% FREE AREA
5'-6"
2" PIPE COL. 3'-0" O.C.
BIN WALL
CROSS BRACE BOTH DIRECTIONS
5/8" RODS
5/8" ROD
2" PIPE 3'-0" O.C.
ROOF DOORS FOR FILLING & EXHAUST AIR - 64 SQ. FT. (BUT NOT LESS THAN 50 SQ. FT.) TOTAL AREA PER BIN
110" AIR PLENUM
#1000 DRYER 30 HP MOTOR BY OWNER
FRESH AIR LOUVRE & SCREEN
SPACE BETWEEN BEAMS OPEN FOR PASSAGE OF AIR
2"×2"×¼" ∠ CONTINUOUS
AS REQUIRED FOR PORTABLE CONVEYOR
1½" PIPE 3'-0" O.C.
SECTION B-B
24'ϕ
24'-ϕ BIN
20 P.S.I. NAT GAS 2 BURNERS 6,200,000 BTU/HR. TOTAL
110" AIR PLENUM
SECTION A-A
MESH
5/8" RE RODS
CONTINUOUS FOOTINGS
CONTINUOUS FOOTING
6'-0"
12"
16"
6"
7802
1 OF 2
Campbell Industries
SCALE 1/8" = 1'-0"

DRAWING # 7

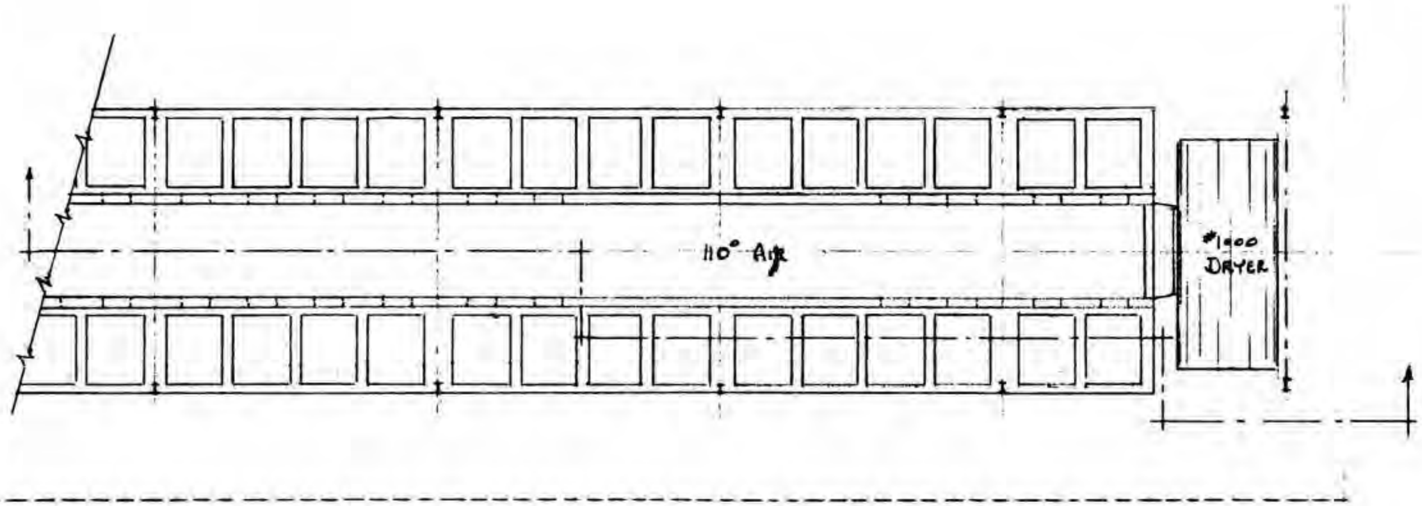


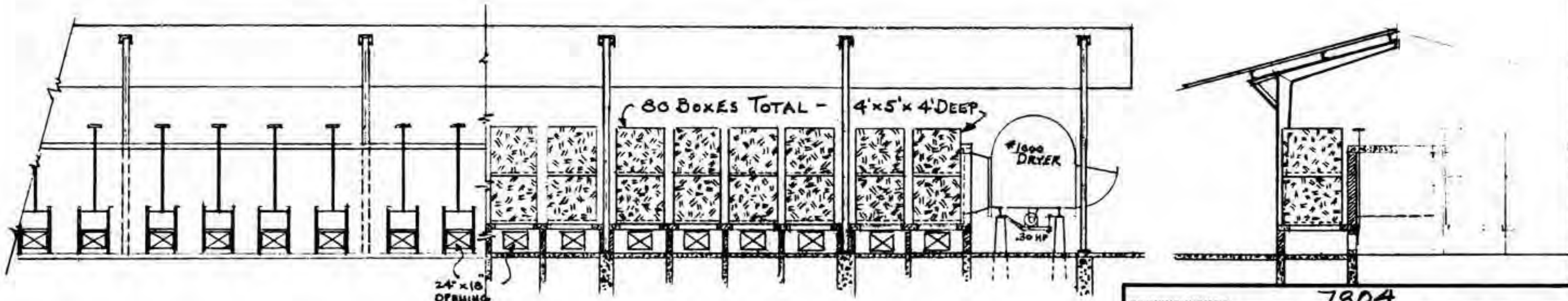
SECTION A-A
BEAM & STEEL FLOOR
BLOWER ROOM
FIRST FLOOR ELEVATION
3 BINS IN 67
2 BINS IN FUTURE
7790
BUILDING LAYOUT FOR 2000 BU. STATIONARY SEED DRYER
NO
REVISION
DATE
BY


#2000 SEED DRYER
CAMPBELL HEATING CO. DES MOINES
7787
180'-0"
16'-0"

DRAWING # 8

DRAWING # 9





DRAWING NUMBER 7804

SCALE 1/8" = 1'-0"
DATE 9-9-66 TRACED
DRAWN BC CHECK
B.P. B.P.
REVISED
DATE BY
DATE BY

Campbell Industries
DES MOINES, IOWA

PROJECT DE KALB AGR
LOCATION DE KALB, ILL

Campbell Industries, Inc.

Since 1880

FORMERLY CAMPBELL HEATING COMPANY

SEED DRYER DIVISION

AREA 515
PHONE 266-5169

3121 DEAN AVE. DES MOINES, IOWA 50317

REQUEST FOR QUOTATION
SEED CORN DRYING INFORMATION, DRYING EAR CORN IN BINS
ALL DATA TO BE GIVEN IN BUSHELS OF SHELLED SEED CORN AT 12% MOISTURE

1. Bushels per season to be dried. ______ bu.
2. Days of drying plant operation allowing for expected weather delays. ______ days
3. "Use Factor" of the bins taking into account emptying and filling time and other causes when bins are not in the drying cycle. We would suggest a use factor of 75% or 80% ______ %
4. Original kernel moisture ______ High ______ % / Average ______ % / Low ______ %
5. If you would like to have us recommend drying system sizes fill in the following:
   a. Number of drying bins desired
      4 bins holding one day's production each would be a minimum but smaller bins and greater numbers might help handle various varieties more easily.
   b. Arrangement of bins ______ All on one side of air duct ______ / On both sides of air duct ______
   c. Drying system ______ Double pass (Campbell System)(100%) ______ / Single pass reversing system (85%) ______ / Single pass one way (80%) ______
   d. Bin filling system
      Describe ______
   e. Bin emptying system
      Describe ______
   f. Type of drying bin construction ______ Frame ______ / Building blocks reinforced ______ / Tip up or poured concrete ______
6. If bins are already constructed or planned send us plans or give us data in Par. 5 above and fill in data below. We will then recommend drying equipment size.
   a. Number and size of bins. ______
   b. Maximum depth of ear corn ______
   c. Size of air passages ______
   d. Size of air doors for each bin above the corn. ______
   e. Size of air doors below the corn. ______
   f. Size of exhaust air doors from each bin. ______

Form D888

OVER

7. Fuel for dryer
The higher the natural gas pressure the less the first cost and the better the burner turn down ratio.

- Nat. Gas less than 5#
- Nat. Gas 5 to 9#
- Nat. Gas 10 to 14#
- Nat. Gas 20 to 29#
- Nat. Gas 30 to 49#

LP gas will probably require a vaporizer to be furnished by LP gas supplier
- LP Gas 30#

- #2 Fuel Oil
- Heavy Fuel Oil

8. Power available
- Single phase
- Three phase
- 60 cycle
- 50 cycle
- 220V
- 440V
- 550V
- 380V

9. Motor Starter
- Across-the-line magnetic
- Part winding starter
- Y Δ starter
- Manual reduced voltage auto trans. starter

10. Type of Motor
- Open drip proof
- Open drip proof with encapsulated winding
- TEFC
- Explosion proof

11. Type of Dryer
- Portable on Skids
- Stationary equipment KD
- Enclosed steel building for stationary equipment
- Steel supports for elevated drying equipment and steel building

12. Shipping instructions
- Rail on flat car
- Truck, common carrier
- Truck, contract hauler
- Truck, sent by purchaser

13. Export Shipping
- Crated for export f.o.b. factory
- Crated for export F.A.S. port
  - Chicago
  - New Orleans
  - New York
- Loaded in container FOB Factory

14. Delivery date desired

Customer Signature

Address Town

CAMPBELL INDUSTRIES, INC.
3121 DEAN AVENUE
DES MOINES, IOWA 50317

12-20-67
Form D888

EFFECTIVE DRYING AND STORAGE OF CORN AND SORGHUM SEED[1/]

James C. Delouche[2/]

Seed drying and storage are separate but closely related phases in an overall seed operation. In both cases, seed moisture content and its control are the main considerations. Basically, drying of seed conditions them to a desirable moisture content while storage maintains moisture content at a favorable level and also protects the seed against injurious pests (rodents, insects) and high temperatures.

Moisture content is the single most important factor involved in the preservation and maintenance of seed quality. It not only controls the rate of physiological degeneration in seed but also the action of other detrimental elements such as heating, molds, and storage insects.

DRYING

Corn and sorghum seed attain physiological and functional maturity at seed moisture contents ranging from 32 to 40%. At that time the seed have reached maximum dry weight, germinability, and vigor. Therefore, during the interval from maturation to harvest, seed are - in effect - stored in the field, which seldom provides a favorable environment for storage.

Harvesting seed after maturation but while they are still high in moisture content poses an immediate and serious problem, for such seed will heat and deteriorate rapidly unless moisture content is quickly reduced to a safe level. The only practical and dependable way to reduce the moisture content of "high moisture" seed is by artificial drying.

1/ Journal Paper No. 1740 of the Mississippi Agricultural Experiment Station. Paper originally presented at 1968 Convention Southern Seedsmen's Association, Dallas, Texas. December, 1968.

2/ Dr. Delouche is Agronomist, In Charge, Seed Technology Laboratory, State College, Mississippi.

For the seed producer, artificial drying offers the following advantages: (1) permits earlier and more timely harvesting, thus, reducing the chances of losses in the field from weather, shattering, mechanical damage, insects and birds; and (2) facilitates storage operations by eliminating the hazard of high moisture.

Seed corn is usually harvested on the ear at moisture contents ranging from 20 to 32%. Thus, drying is always necessary. On the other hand, sorghum seed produced in the Southwest under relatively good field drying conditions are frequently allowed to dry in the field and only aerated after harvest. Nevertheless, most sorghum seed producers have facilities for artificial drying when and if it is needed.

Seed drying involves a two phase system consisting of air and seed. In order to understand the principles of drying, some knowledge of pertinent seed and air characteristics or properties is necessary.

Properties of Air:

Air consists of a mechanical mixture of gases and suspended solids (dust, pollen, etc.). The more important gases are oxygen (20%), nitrogen (79%), carbon dioxide (0.03%), and water vapor (0 to 4%). Within normal temperature ranges, the gaseous composition of air remains relatively constant except for the water vapor component.

The actual weight of water vapor contained in a given volume of air is referred to as absolute humidity. Absolute humidity is expressed in grains[3] or pounds of water vapor per cu. ft. of air. Absolute humidity does not indicate relative dryness or moistness of air - it only indicates actual moisture content.

Air is capable of holding moisture in an amount related to its temperature. If a given volume of air contains all the moisture that it can hold at a constant temperature and pressure, it has reached its maximum limit of absolute humidity and is said to be saturated and to have a relative humidity of 100%. Air that contains only 50% of its maximum capacity is only half saturated and has a relative

---

3/ 7000 grains = 1 pound.

humidity of 50 percent. Thus, relative humidity is the ratio (expressed as percentage) of the amount of water that the air actually contains and the amount that it would contain under constant temperature and pressure if fully saturated. Relative humidity is, therefore, a measure of the relative moistness or dryness of air.

Three relationships among temperature, relative humidity and drying capacity of air are of paramount importance in seed drying. These are (see Table 1):

1. WHEN AIR IS HEATED, ITS RH DECREASES, AND ITS VOLUME EXPANDS.

   Example: Ambient conditions are 60°F. and 80% R.H. If the air is heated to 100°F., RH decreases to 21% and volume increases from 13.1 to 14.1 cu. ft./lb./ dry air.

2. DRYING CAPACITY OF AIR INCREASES AS RH DECREASES.

   Example: 60°F. - 80% RH air contains 62.05 grains moisture lb./dry air. At the same temperature it can hold 77.65 grains moisture at saturation (100% RH). Therefore, drying capacity is 77.65 - 62.05 = 15.51 grains/lb./air. If RH were lowered to 20%, the air would contain only 15.5 grains/lb. and drying capacity would be increased to 77.65 - 15.50 = 62.15 grains/lb. or approximately 4 times greater than previously.

3. DRYING CAPACITY OF AIR INCREASES AS TEMPERATURE INCREASES AT CONSTANT TEMPERATURE.

   Example: 60°F. - 80% RH air has a drying capacity of 15.51 grains/lb./air. Air at 100°F. - 80% RH has a drying capacity of 302.3 (content at saturation)-241.8 (content at 80% RH) = 60.50 grains/lb., or 4 times greater than the cooler air.

Table 1. Effect of temperature rise on relative humidity of air.

Natural Air Temperature Fahrenheit	Temperature Rise Degrees F.	Relative Humidity of Natural Air 100%	90%	80%	70%	60%	50%
	H_2O/lb. of Air*	15.06	13.55	12.05	10.54	9.04	7.53
	20	41	37	33	29	25	21
	30	28	25	21	20	17	14
	40	19	18	16	14	12	10
20°	50	14	12	11	10	8	7
	60	10	9	8	7	6	5
	70	7	6	6	5	4	3
	80	5	5	4	4	3	3
	90	4	3	3	3	2	2
	H_2O/lb. of Air*	24.18	21.76	19.34	16.93	14.51	12.09
	10	66	60	53	46	40	33
	20	45	41	36	32	27	23
	30	31	28	25	22	19	16
30°	40	22	20	18	15	13	11
	50	16	14	12	11	9	8
	60	11	10	9	8	7	6
	70	8	7	6	6	5	4
	80	6	5	5	4	4	3
	H_2O/lb. of Air*	36.49	32.84	29.19	25.54	21.89	18.25
	10	68	61	54	48	41	34
	20	47	42	38	33	28	24
	30	33	30	26	23	20	17
40°	40	23	21	19	16	14	12
	50	17	15	13	12	10	8
	60	12	11	10	8	7	6
	70	9	8	7	6	5	4

Table 1. Continued.

	H_2O/lb. of Air*	100%	90%	80%	70%	60%	50%
		53.62	48.26	42.89	37.53	32.17	26.81
50°	10	69	62	55	48	42	35
	20	48	44	39	34	29	24
	30	34	31	27	24	21	17
	40	25	22	20	17	15	12
	50	18	16	14	12	11	9
	60	13	12	10	9	8	6
	H_2O/lb. of Air*	77.56	69.80	62.05	54.29	46.54	38.78
60°	10	70	63	56	49	42	35
	20	50	45	40	35	30	25
	30	36	32	28	25	21	18
	40	26	23	21	18	15	13
	50	19	17	15	13	11	9
	H_2O/lb. of Air*	110.7	99.63	88.56	77.49	66.42	55.35
70°	5	84	76	67	59	50	42
	10	71	64	57	50	43	35
	15	60	54	48	42	36	30
	20	51	46	41	36	30	25
	25	43	39	34	30	26	22
	30	37	33	29	26	22	18
	35	31	28	25	22	19	16
	40	27	24	21	19	16	13
	H_2O/lb. of Air*	131.7	118.53	105.36	92.19	79.02	65.85
75°	5	84	76	67	59	51	42
	10	71	64	57	50	43	36
	15	60	54	48	42	36	30
	20	51	46	41	36	31	26
	25	44	39	35	31	26	22
	30	37	33	30	26	22	19
	35	32	29	25	22	19	16

Table 1. Continued.

		100%	90%	80%	70%	60%	50%
	H_2O/lb. of Air*	156.3	140.67	125.04	109.41	93.78	78.15
	5	85	76	68	59	51	42
	10	72	64	57	50	43	36
80°	15	61	55	49	43	37	30
	20	52	44	41	36	31	26
	25	44	40	35	31	26	22
	30	38	34	30	26	23	19
	H_2O/lb. of Air*	184.9	166.41	147.92	129.43	110.94	92.45
	5	85	76	68	59	51	42
	10	72	65	58	50	43	36
85°	15	61	55	49	43	37	31
	20	52	47	42	37	31	26
	25	44	40	36	31	27	22
	H_2O/lb. of Air*	218.3	196.47	174.64	152.81	130.98	109.15
	5	85	76	68	59	51	43
90°	10	72	65	58	51	43	36
	15	62	55	49	43	37	31
	20	53	47	42	37	32	26
	H_2O/lb. of Air*	257.1	231.39	205.68	179.97	154.26	128.55
	5	85	77	68	60	51	43
95°	10	72	65	58	51	44	36
	15	62	56	49	43	37	31
	H_2O/lb. of Air*	302.3	272.07	241.84	211.61	181.38	151.15
	5	85	77	68	60	51	43
100°	10	73	65	58	51	44	36

* The absolute moisture content for each temperature and relative humidity condition is given in grains/lb. of dry air. 7000 grains = 1 lb.

NOTE: The relative humidity values are given to the nearest whole percent.

These examples dramatically point up the reasons why heated air drying is used when seed moisture content is high and drying has to be rapidly accomplished. Yet, we did not even consider the total increase in drying capacity resulting from heating 60^{o}F. - 80% RH air to 100^{o}F. When this is done, drying capacity increases from 15.51 to 240.25 grains/lb./dry air.

Properteis of Seed:

Seed are hygroscopic. That is, they have the capacity to absorb moisture vapor, or to lose moisture as vapor. When seed and air are mixed, the vapor pressures of the moisture in the air and the mosture in the seed tend to equalize - and they will equalize if confined to a given space and sufficient time is allowed. As the vapor pressures equalize an equilibrium is established and there is no net change in seed moisture content of the seed or in relative humidity of the air. The moisture content that seed attain when subjected to a given level of relative humidity is referred to as the hygroscopic equilibrium value or equilibrium moisture content. The equilibrium moisture content of seed at a given level of relative humidity varies with chemical composition of the seed and temperature. In high oil content seed such as soybeans it is lower than that of starchy seed such as corn at all levels of relative humidity below 90% and at the same temperature. Equilibrium moisture content also increases slightly as temperature decreases and decreases in the same proportion as temperature increases. The equilibrium moisture contents of several important kinds of seed are given in Table 2.

Table 2. Equilibrium moisture contents of six kinds of seed. (Wet weight basis at 77^{o}F.).

	Relative Humidity (%)					
Kind	15	30	45	60	75	90
Cotton	---	6.0	7.5	9.1	12.8	18.0
Corn, YD	6.4	8.4	10.5	12.9	14.8	19.1
Rice, rough	5.6	7.9	9.8	11.8	14.0	17.6
Sorghum	6.4	8.6	10.5	12.0	15.2	18.8
Soybeans	---	6.2	7.4	9.7	13.2	----
Wheat, soft red	6.3	8.6	10.6	11.9	14.6	19.7

Seed will lose moisture (dry) when their actual moisture content is higher than that in equilibrium with the relative humidity of the surrounding air. Conversely, they will absorb moisture when their moisture content is lower than the equilibrium value for the prevailing level of relative humidity.

Equilibrium moisture content sets the limits to which drying can be accomplished under a given set of conditions. Air at 100°F. - 25% relative humidity will dry corn and other grain seed to below 8% and soybean and cottonseed to below 6%, but air at 100°F. and 75% R.H. will dry the grains no lower than about 14% and cotton and soybeans no lower than 12.5 to 13.0%. Moreover, in the latter case, drying would be very slow.

Another most important property of seed should not be overlooked. Seed are alive and drying accomplishes nothing if viability is adversely affected by high air temperature. Generally, the seeds of corn, wheat, sorghum or similar grains are dried at air temperatures between 100-110°F. but no higher than the latter. High oil content seed such as those of peanuts, soybeans, etc. are dried at a somewhat lower air temperature.

The Drying System:

Drying is accomplished by moving air around the individual seeds or ears in a moving or stationary mass. In heated air drying the system required to dry seed consists of a bin to hold or confine the seed, a burner to heat the air, a fan to force the heated air through the mass of seed, and controls. For our purposes here a detailed discussion of the various components of the drying system is not necessary. Campbell's paper in this Proceedings thoroughly considers the total drying system. We will only say here that corn is most often dried on the ear in single or double circulation bins. The heated air is forced up through or down through the mass of ears, or alternately up and downward to achieve more uniform drying. Sorghum seed can be dried in bins or in a continuous flow type dryer.

Effective drying requires that the burner be able to deliver sufficient BTU's of heat to raise air temperature to 100 to 110°F., that the fan be able to deliver the required volume of air (10 to 30 cfm/bu.) against the static pressure developed by the depth of seed dried, and that temperature be accurately controlled within safe limits.

Rate of Drying:

Seed drying involves two transfers of moisture: (1) surface moisture to the air stream; and (2) internal moisture to the seed surface. The rate at which these transfers are accomplished determines the rate of drying. In turn the rate of moisture transfer is influenced by:

1. DRYING CAPACITY OF AIR
2. RATE OF AIR FLOW
3. PHYSICAL PROPERTIES OF THE SEED

Generally, rate of drying should be as rapid as possible without injury to the viability or vigor of the seed, and conspicuous and unnecessary waste of energy.

STORAGE

The properties of air and seed discussed previously are equally applicable in storage. The main purpose of storage is to maintain seed quality. This is best accomplished by storing high quality, well dried seed under conditions that will prevent any regain in seed moisture content and provide for reasonably moderate storage temperatures.

The general perscription for storage is that conditions should be dry and cool. A perscription such as this is meaningless unless specific levels or at least ranges of moisture content and temperature are given. And these can not be given unless the desired period of storage is known.

Corn and sorghum seed will store quite well for one season at a moisture content of 11 to 12% and normal warehouse temperatures. Storage periods longer than one season (carryover) require seed moisture contents of about 10% and some protection against high summer temperature for maintenance of viability and vigor. Long term storage of valuable seed stocks requires still more rigorously controlled conditions - relative humidity of 40% or less and temperature of 50°F. or less.

SUMMARY

Seed drying and storage both involve conditioning of seed moisture content. Drying rapidly and effectively removes moisture from seed harvested at the peak of quality and reduces moisture content to a safe level. The main objective of storage is maintenance of high seed quality by holding seed moisture content down to a desirable level (10-12% for corn and sorghum), and providing for moderate temperatures, and protection against rodents, and insects.

SYSTEMS FOR CONTROLLING RELATIVE HUMIDITY AND TEMPERATURE

James M. Beck[1/]

The general requirement for good seed storage is a dry and cool environment. Seed operations located in climatic areas with high temperatures and relative humidities must have some system of controlling both the relative humidity and the temperature of the air inside seed storage rooms. Sealed storage (vapor proof containers) has been used for many years in the vegetable seed industry; however, two factors have limited the use of this method for storage of field crop seeds: (1) the cost of vapor proof containers, and (2) the moisture content of the seed must be 2-3% lower than that normally considered safe for seed packaged in non-moisture proof containers.

Before considering several systems that can be installed to maintain low relative humidities and temperatures, let us consider the basic requirements. First, a structure must be provided that will keep infiltration of moisture and heat to a minimum; second, there must be some means for dehumidification (removing moisture from the air); and third, there usually must be some provision made for lowering the temperature of the air.

STORAGE ROOM CONSTRUCTION

The question of how to build a good seed storage room becomes a question of what is the best way to construct a "large container" and make it as air tight as possible. This is necessary in order to keep the initial cost and the operating expense of the dehumidifying and cooling equipment at a minimum.

For low humidity conditions, it is essential that adequate vapor barriers be included in the construction and that they be installed with the greatest of care making sure that all joints are properly sealed. Thermal insulation requirements will vary with geographic location.

[1/] Mr. Beck is Engineer Technician, Seed Technology Laboratory, Mississippi State University.

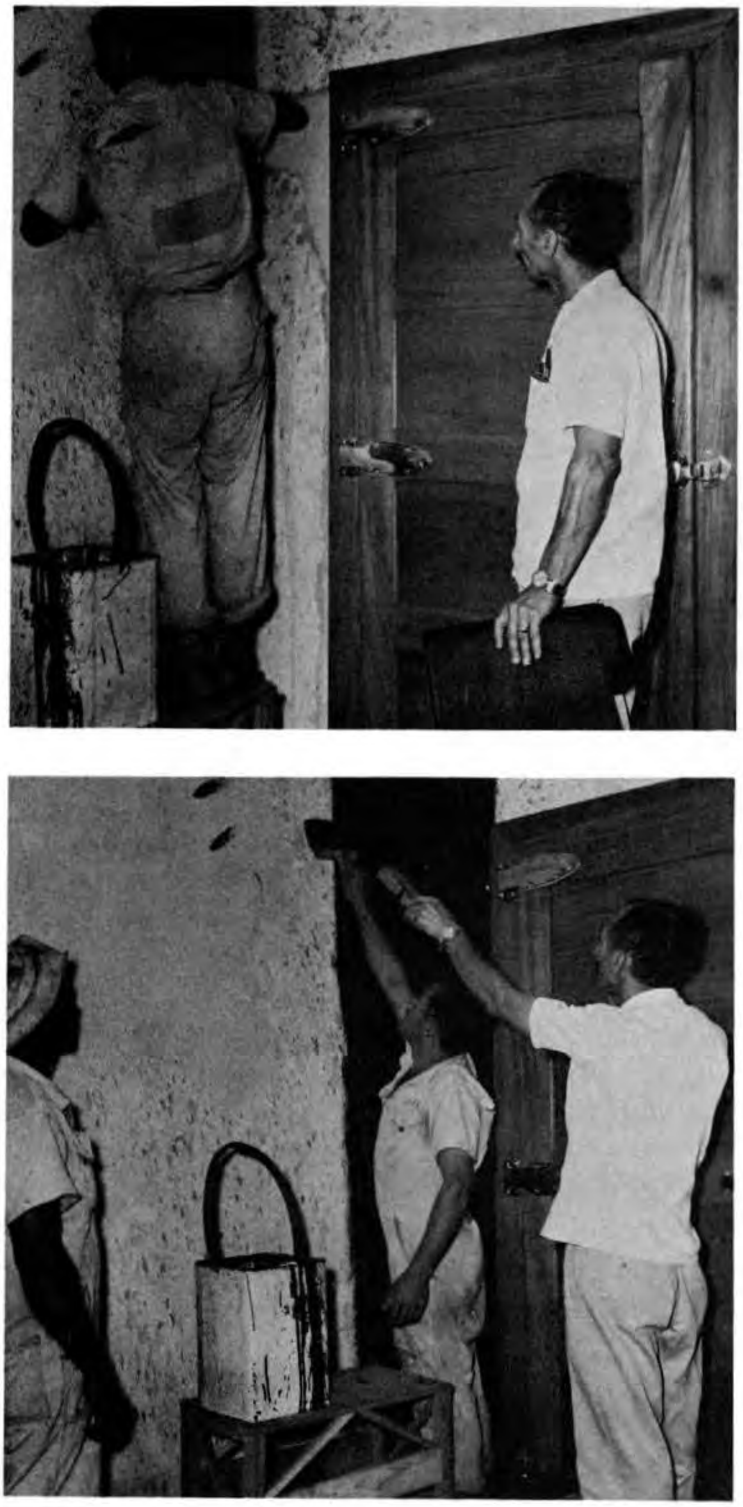


Figure 1. Foil-laminated vaporseal applied with asphalt compound to eliminate danger of moisture entering seed storage room when cracks develop.

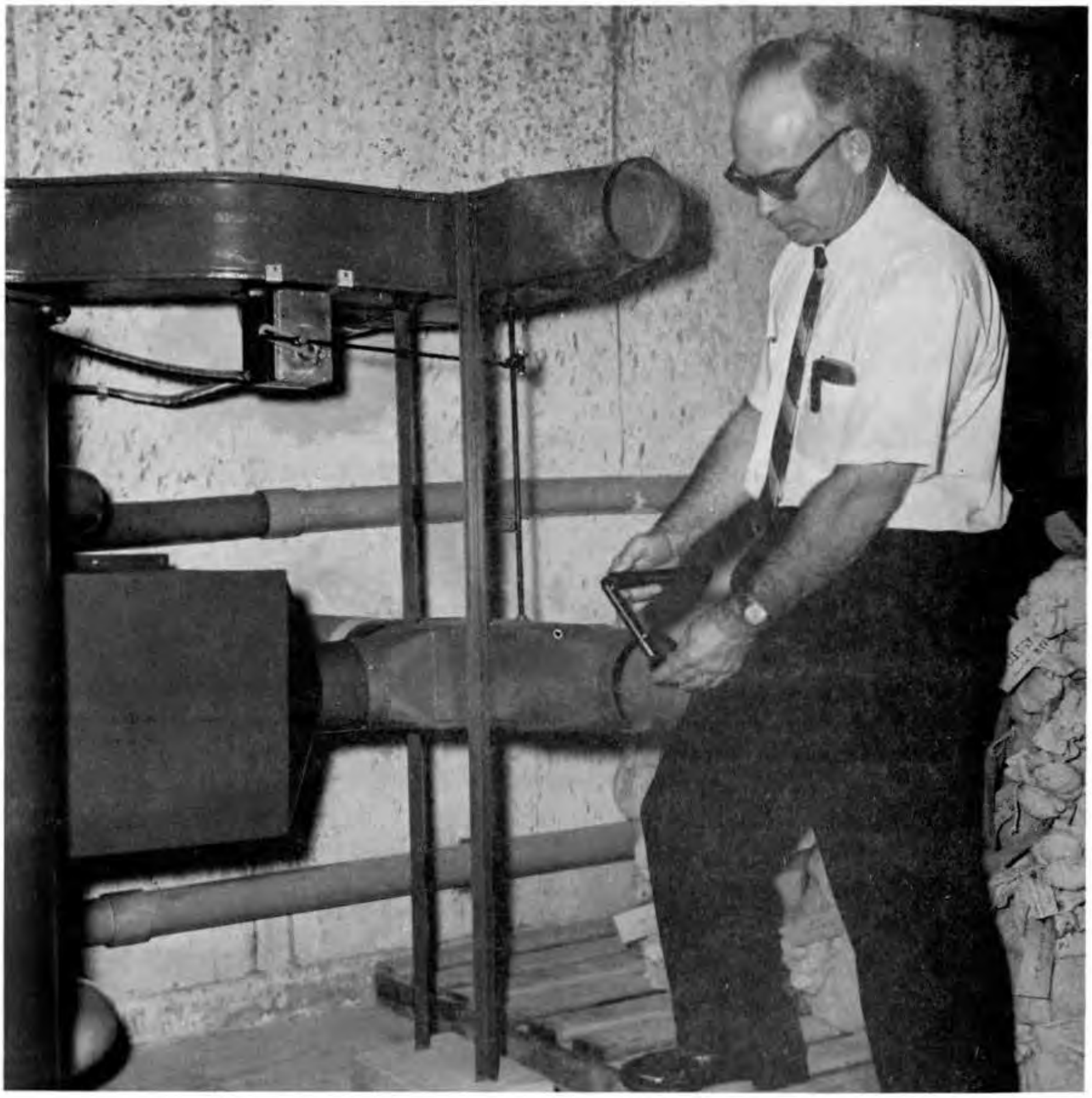


Figure 2. A single desiccant type dehumidifier with an automatic valve system used to maintain different relative humidities in two rooms at different temperatures. A sling psychrometer measures the dry bulb and wet bulb temperature of the air delivered from the desiccant unit.

Obviously, the size of the storage area should not be larger than absolutely necessary. If seeds are to be stored in a large warehouse, it is more economical to condition only a small portion of the warehouse rather than to attempt to dehumidify and cool the entire structure.

DEHUMIDIFICATION

Generally speaking, there are two major categories of dehumidifiers: refrigeration-type and chemical or adsorption-type.

Refregeration-Type:

The refrigeration-type dehumidifier operates by drawing warm moist air over a metal coil through which a refrigerant such as Freon is circulated. A part of the atmospheric moisture condenses on this cooling coil and is collected in a pan or bucket or is drained off. The cooled air coming from over the coil which now has a low temperature and a high relative humidity is reheated by the condenser coil of the refrigeration system; thus raising the temperature and lowering the relative humidity.

The water removal capacity of this type of system is dependent on the difference in temperature between the entering air and the cooling coil. While these units are quite effective at high temperatures, they lose efficiency below 70°F. or 50% relative humidity. Heat from the electric motors that drive the compressor and fans add sensible heat to the atmosphere.

Adsorption Type:

The adsorption-type dehumidifier operates by drawing moist air over a solid drying agent (desiccant) which has the ability to extract and retain moisture on its surface by a phenomenon known as "adsorption." The air is filtered and dried to a very low dew point in the process, and the desiccant is periodically regenerated by means of heated outside air which vaporizes the moisture and dispels it to the outside of the conditioned space. Continuous operation of these machines is achieved by either using two desiccant beds which switch back and forth automatically, or by using rotating

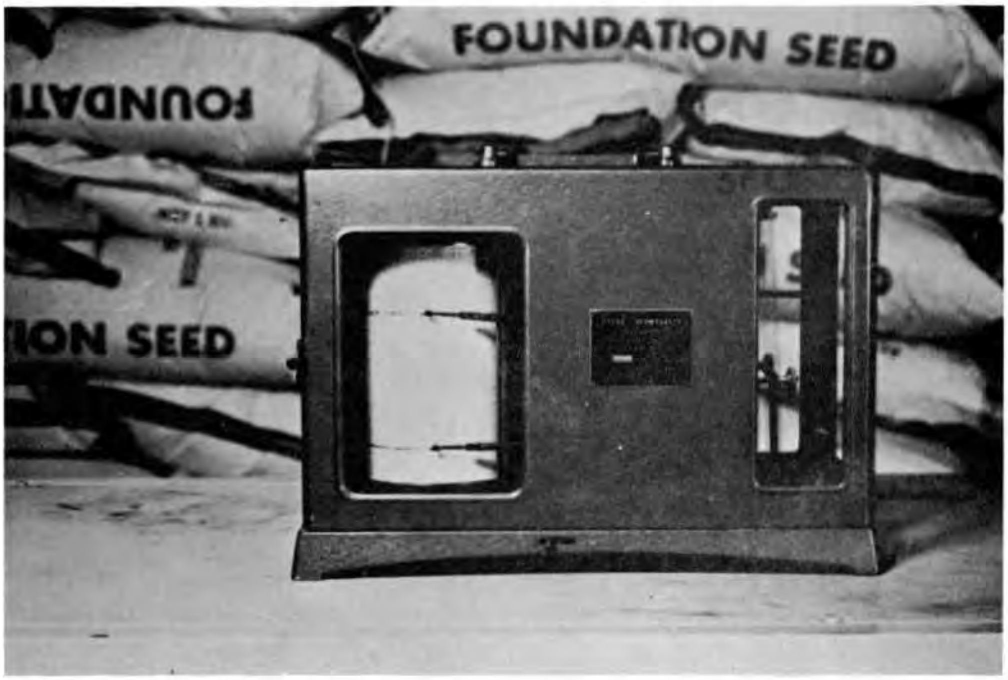


Figure 3. Foundation seed stored under low temperature, low relative humidity conditions. Hygrothermograph records the temperature and relative humidity of the air.

Figure 4. A sling and psychrometric chart is used to determine the properties of air inside a seed storage room.

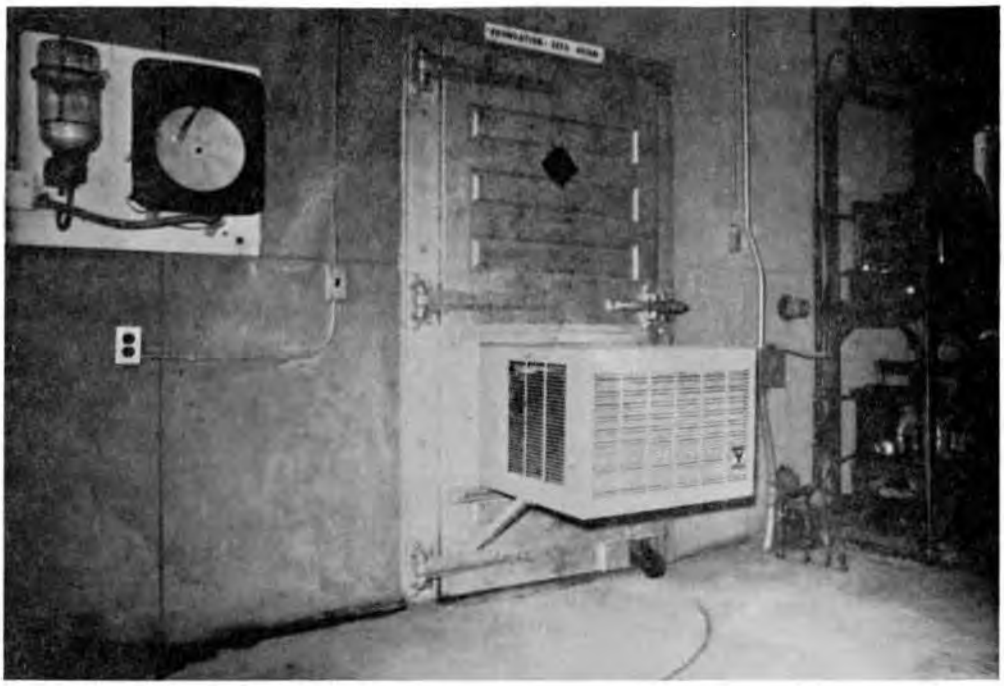


Figure 5. A conventional type window airconditioner can be used to control the temperature inside a seed storage room if the relative humidity is controlled by a separate dehumidifier.

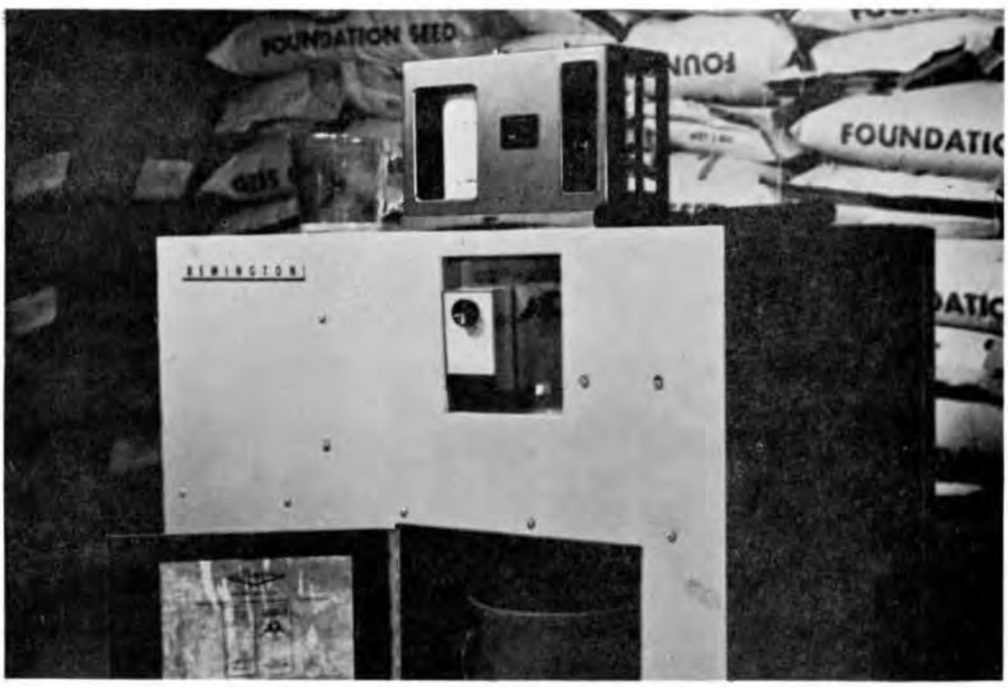


Figure 6. A refrigeration type dehumidifier located inside a seed storage room. Moisture is condensed out of the air and collected in a bucket or piped out of the room.

beds of desiccant, a portion of which is always dehumidifying the air, while the remainder is being regenerated.

Desiccant dehumidifiers provide maximum efficiency at low temperatures, and are able to maintain constant relative humidities even below 10%. A factor that should not be overlooked is that heat is added to the controlled atmosphere even though the unit is placed outside the storage room. The latent heat of vaporization of the moisture that is removed is converted to sensible heat. There is also a certain amount of residual heat left in the desiccant after reactivation which increases the air temperature.

Heat Removal:

Since an excessive heat build-up will usually be experienced when either type dehumidifier is used along to reduce the relative humidity in a seed storage room, let us consider several means of removing this heat. The most common and familiar method is by using a refrigeration-type air conditioner, which can also be used to "dehumidify." It operates in a manner similar to the refrigerant dehumidifiers except that it has a larger cooling coil area and provides air or water cooling of the condenser coils.

Water after-coolers can be used with a desiccant type dehumidifier if the sensible heat load of the storage room is not excessive and a supply of cool water is available. Pre-cooling and after-cooling coils that are cooled by a refrigeration system is a most efficient way of removing large amounts of moisture with a desiccant dehumidifier. At temperatures below 50°F., silica gel will remove nearly 90% of the moisture from the air stream. At 100°F. this removal ratio is only about 50%.

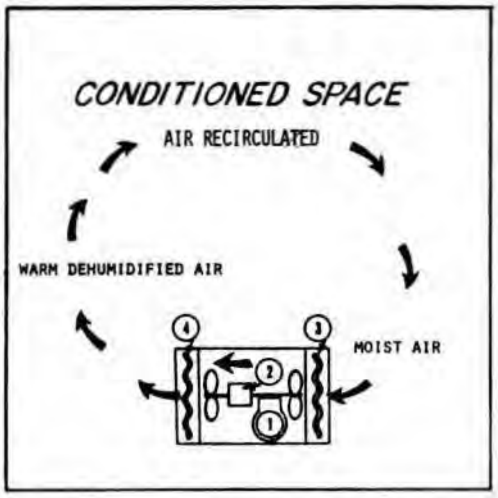
Depending upon the temperature, relative humidity requirement, the moisture, and sensible heat load, one method or system is usually more efficient than another. Therefore, let us consider eight possible systems for maintaining the required temperature and relative humidity in a conditioned seed storage facility.

DEHUMIDIFICATION SYSTEM - TYPE I

As shown in the first illustration, a refrigeration-type dehumidifier is placed inside the conditioned space. This self-contained unit consists of the following components: refrigeration compressor, motor and fans, evaporator and condenser coils. The air inside the room is recirculated through the unit until the set relative humidity is reached and a humidity control switch in the electrical circuit shuts the unit off. The humidistat will automatically turn the unit on again when the moisture content of the air begins to increase due to infiltration or movement of moisture from the storage product or from other moisture sources inside the room. This system can be used satisfactorily only in locations where temperature control is not necessary; that is, where the sensible heat increase does not raise the air temperature above safe limits.

DEHUMIDIFICATION SYSTEM - TYPE II

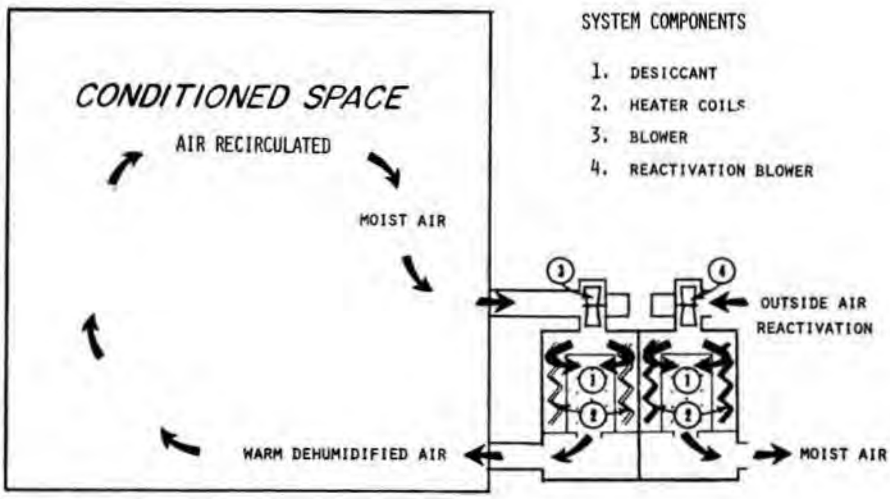
The second illustration shows a desiccant dehumidifier located outside the conditioned space. This self-contained desiccant unit has the following components: desiccant (usually silica gel), heater coils, conditioned air blower and reactivation blower. The air in the conditioned space, through a closed system, is recirculated through the unit until the set relative humidity is reached. A humidistat, located inside the conditioned space, controls the running of the conditioned air blower. Most desiccant dehumidifiers are wired so that the reactivation cycle continues even though the conditioned air blower stops. This is desirable only when the unit must run most of the time to maintain the relative humidity in the conditioned space; otherwise, the result is excessive heat and expense. By having the reactivation heaters and fan wired to shut off when the conditioned air blower shuts off and by locating the machine outside the conditioned space, the heat build-up can be kept to a minimum.



SYSTEM COMPONENTS

1. COMPRESSOR
2. MOTOR AND FANS
3. EVAPORATOR COIL
4. CONDENSER COIL

DEHUMIDIFICATION SYSTEM, TYPE I



SYSTEM COMPONENTS

1. DESICCANT
2. HEATER COILS
3. BLOWER
4. REACTIVATION BLOWER

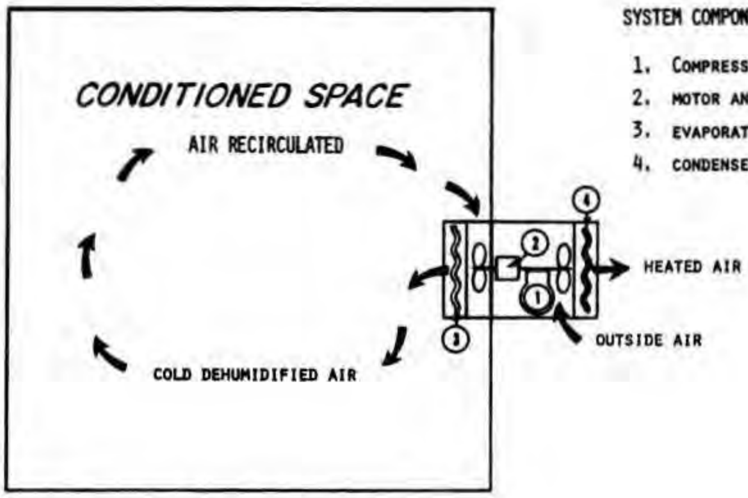
DEHUMIDIFICATION SYSTEM, TYPE II

DEHUMIDIFICATION AND COOLING SYSTEM - TYPE III

A conventional type air conditioner can be used to maintain temperature and relative humidity when the reduction of temperature is necessary for control of the sensible heat load. As shown in the third illustration, only the evaporator section of the refrigeration unit is placed inside the conditioned space. The air within the conditioned space is recirculated over the cold evaporator coil, where moisture is condensed out. Outside air is drawn over the condenser coils releasing the transferred heat to the atmosphere. The unit is controlled by a thermostat that shuts the compressor off when the temperature of the the inside air is reduced to the set condition. Since moisture is condensed out only when the room temperature is not satisfied, sizing of the air conditioner for the sensible heat load becomes critical. The compressor must run to keep the evaporator coils cold if dehumidification is to be accomplished. To maintain a more constant relative humidity condition, electric heater strips are sometimes used to add heat to the air which will keep the unit running for longer periods. If these heater strips are connected thru a humidistat, they canbe turned on and off automatically as the humidity inside the conditioned space changes.

DEHUMIDIFICATION AND COOLING SYSTEM - TYPE IV

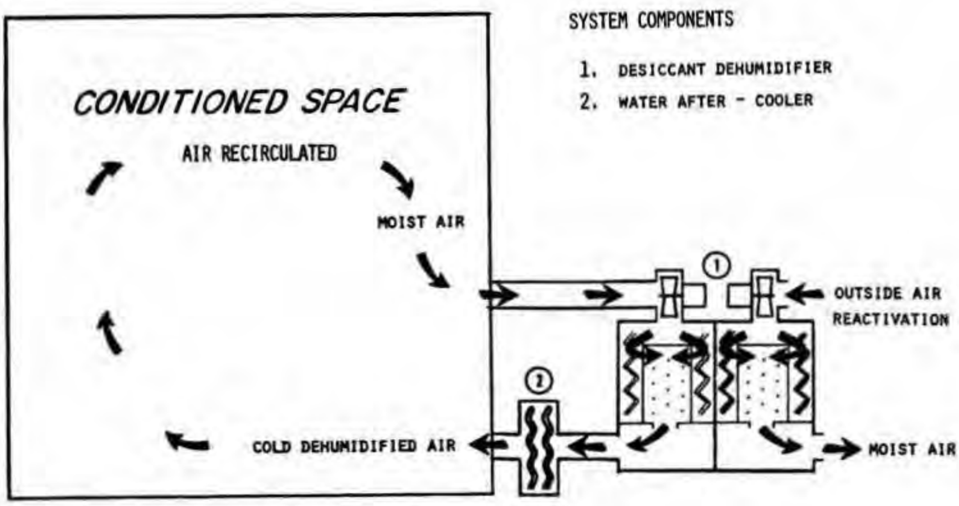
The system shown in the fourth illustration consists of a desiccant dehumidifier with a water after-cooler. The water cooler is used to reduce the air temperature as it leaves the desiccant dehumidifier. The size of the after-cooler coil and the quantity and temperature of the water that passes through the coil will determine the amount of heat that can be removed. This system is very effective for maintaining low humidities and temperatures in the range of 5-10 degrees above the water temperature. A magnetic valve can be used in the water supply system to automatically regulate the water flow, thus keeping the air temperature within set limits.



SYSTEM COMPONENTS

1. COMPRESSOR
2. MOTOR AND FANS
3. EVAPORATOR COIL
4. CONDENSER COIL

DEHUMIDIFICATION AND COOLING SYSTEM, TYPE III



SYSTEM COMPONENTS

1. DESICCANT DEHUMIDIFIER
2. WATER AFTER - COOLER

DEHUMIDIFICATION AND COOLING SYSTEM, TYPE IV

DEHUMIDIFICATION AND COOLING SYSTEM, TYPE V

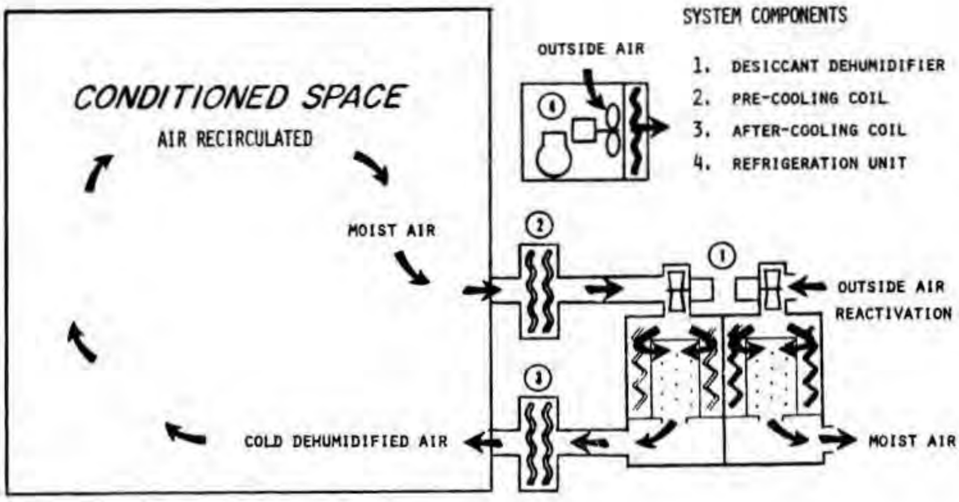
The fifth illustration shows a high moisture removal system that utilizes a refrigeration unit in conjunction with a desiccant dehumidifier. Cooling for a pre-cooling coil and an after-cooling coil is provided by the refrigeration system. Since silica gel can remove nearly 90% of the moisture from air at a temperature below $50^{o}F.$, the air in the conditioned space is first cooled by passing through the pre-cooling coil before contacting the desiccant in the dehumidifier. In the process of adsorption, latent heat of condensation is converted into sensible heat. Because this sensible heat increase may increase the air temperature as much as $50^{o}F.$, the after-cooling coil is necessary to reduce the temperature to safe limits. With automatic controls the temperature of both cooling coils can be regulated thus making it possible to maintain low humidities and temperatures inside the conditioned space to close tolerances under a wide range of load conditions.

DEHUMIDIFICATION AND COOLING SYSTEM - TYPE VI

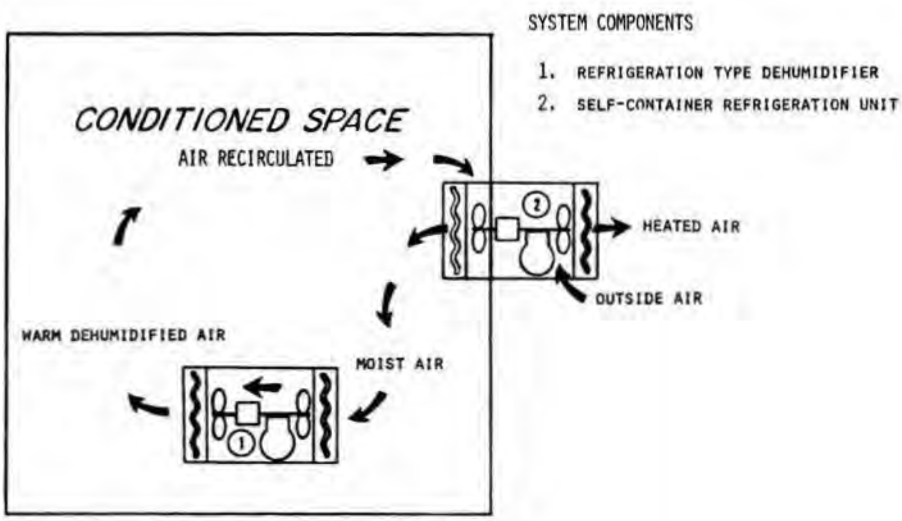
A simple system for controlling the temperature inside a conditioned space while removing large quantities of moisture at higher temperatures is shown in the sixth illustration. A self-contained refrigeration type dehumidifier located inside the conditioned space to remove the moisture from the air is controlled by a humidistat. The sensible heat load is handled by a refrigeration unit that transfers the heat to the outside atmosphere. The air temperature inside the conditioned space is kept within set limits by a thermostat that turns the refrigeration compressor on and off. Of course this type system looses efficiency at temperatures below $70^{o}F.$ and relative humidities below 50%.

DEHUMIDIFICATION AND COOLING SYSTEM -TYPE VII

A dual system, as shown in illustration 7, can be designed to maintain low humidities and low temperatures in the conditioned space over a wide range of load conditions.



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE V



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE VI

The refrigeration systems will dehumidify (within limits of design) as well as cool the air. It works independently of the desiccant unit; however, in normal operation the two systems complement each other. The desiccant dehumidifier has a much higher moisture removal capacity by having cold moist air entering the machine. Under extreme load conditions, the air temperature leaving the unit could be high enough to pick up sufficient moisture before entering the evaporator that a certain amount of water would be condensed out on the cold coils.

Since either system can lower the humidity to a certain extent, this dual system offers a safety factor in case of mechanical failure.

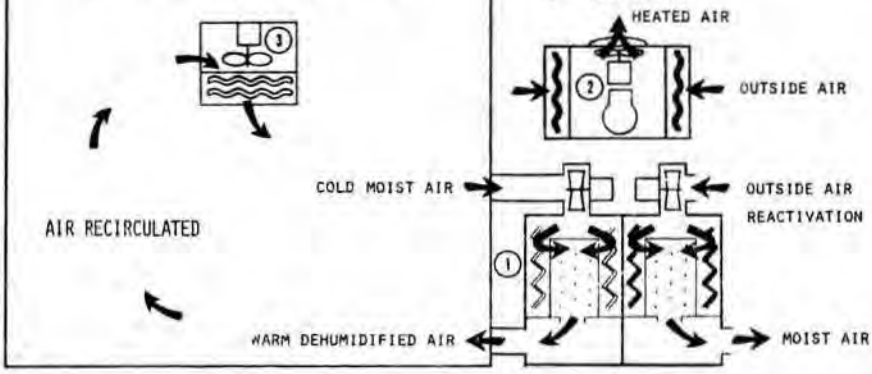
DEHUMIDIFICATION AND COOLING SYSTEM - TYPE VIII

A mechanical refrigeration system, as shown in illustration 8, can be designed to maintain low humidities as well as low temperatures inside a conditioned space. Since the evaporator coil temperature must be below the dew point of the conditioned air at low temperatures and relative humidities, the moisture that condenses out will freeze, forming ice on the coils. Some provision must be made to melt this ice and remove it as water from the conditioned space. In the illustration, a hot gas defrost system is shown. By use of a time clock, hot discharge gas from the refrigeration compressor is directed through the evaporator coil at regular intervals.

It should be pointed out that a refrigeration system that will function well at temperatures below 70°F. and 50% relative humidity is not composed of standard "comfort" or "cold storage" refrigeration components -- humidity control must be built into the coil design and other components of the system.

SYSTEM COMPONENTS

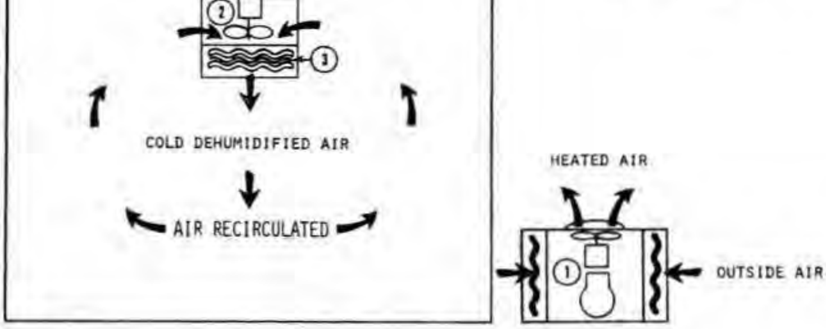
1. DESICCANT DEHUMIDIFIER
2. REMOTE REFRIGERATION UNIT
3. EVAPORATOR



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE VII

SYSTEM COMPONENTS

1. REMOTE REFRIGERATION UNIT
2. EVAPORATOR
3. HOT GAS DEFROST SYSTEM



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE VIII

SEED TREATMENT AND TREATERS

C. Hunter Andrews[1/]

Two hundred and ninety-eight years ago seedsmen and farmers of England were experiencing a disastrous plague in their grain and seed fields. Instead of fine plump wheat kernels, the plants bore only thousands of black, dusty spores. Instead of adequate grain supplies the storage bins had become dangerously low in supply.

Whether to replenish the shrinking supply of grain or to provide the farmers with a fresh source of "clean" seed, a British frigate was cautiously navigating her way through the challenging waters of the dark channel. However careful the captain might have been, he did not prevent the ship from foundering, thus loosing the entire cargo of precious grain to the vicious waters of the deep.

Possibly the local farmers received word of this diaster or maybe they just investigated the cause of the vast numbers of birds darting down on the sandy beaches - what ever the reason, the bright wheat kernels which they found washed ashore certainly could be no worse than the black discolored seed which presently filled their storage rooms.

The curious ones planted some of this seed. Low and behold the "Black Plague" was either absent or greatly reduced in their growing crop. The not-so-lucky neighbors who may have been at first suspicious of this "watered" seed marveled at this magic. Not really knowing the actual cause of the "Black Grain Plague," these pioneering seedsmen were quick to realize that at least in part, their troubles had been relieved.

This, an often repeated story, marks an important historical date for this was the first attempt at seed treatment. Indeed, washing seed in sea water before planting became a common practice for controlling stinking smut or bunt for the next century.

[1/] Dr. Andrews is Assistant Agronomist, Seed Technology Laboratory, State College, Mississippi.

Naturally, any subsequent attempts at improving materials and methods of seed treatment were centered in Europe - a lye and lime treatment first, then a soak treatment with copper sulfate Following the revolutionary method of soaking grain in hot water to control smut, both the U.S. and European scientists began to recommend formaldehyde as a seed treatment.

With the advent of WW I, a dust treatment for wheat, copper carbonate, was introduced. However, due to its limitations in controlling smut, it failed to replace formaldehyde as an effective seed treatment for oats and barley.

Organic mercurys were introduced as seed treatments in the 20's with good effects in controlling seed-rot and seedling blight diseases. Next, dust treatments became very popular as on-the-farm applications due to their ease of application and time saving methods.

W.W.II caused drastic cut-backs in available mercury; thus non-mercurial treating agents were developed. With their higher safety level of application, seeds here-to-fore sensitive to mercurials were nowincluded in the recommended list for treatment with the non-mercurials.

Of considerable importance after the war was the closer cooperation among the equipment companies and chemical companies which resulted in better treatment formulations and machines with which to apply them. Slurry treatments were improved, direct liquid treatments were introduced and precision treaters with accurate metering systems became commonplace. Thus, treating hazards were minimized - seed treatment became an important commercial aspect of the seed trade. Yes, and today research continues to bring about periodic innovations in seed treatments and treaters.

Seed treatment products are quite numerable, differing in some small degree in their specificity and chemical formulation. This is no wonder when considering the vast array of fungi, bacteria, viruses, nematodes and other pests which destroy millions of dollars worth of seeds annually. An ideal seed treatment must be highly effective in controlling some specific pathogenic organism. And in addition it should:

1. Be harmless to the seed, even at higher applications than the recommended rate,(beware of the saying, "if a little does a little good, then a lot should do lots of good.")

2. Be stable for relatively long periods of time - as a product on the shelf and as a coating on the seed which may be stored for an extended time prior to planting.

3. Give an even coating to the seed, adhere well, and not impart a dull or unattractive appearance or impair seed flow in any manner.

4. Be relatively non-toxic to people or to animals.

5. Be easy to use.

6. Compete cost-wise with already available products.

Thus, the ideal treatment has yet to be developed!

The notable treater manufacturers of today are not nearly so numerous as the treatment materials, but this is not to say that the mechanical treaters have been neglected. Indeed, they have not. From the antiquated methods of inaccurately applying offensive treatments, there exists today highly sophisticated machines for accurately metering extremely small quantities of materials and thoroughly mixing them with the seed for adequate coverage and protection.

Dust treaters were among the first used, probably as a result of the popularity of the dust treatment formulations. Some of these machines are still in existence today, even with up-to-date improvements.

As the wettable powders were introduced as treatment materials, the slurry treater came into being. The accuracy of the simple slurry cup and the seed dump pan once again revolutionized commerical seed treating. The cup metered a given amount of slurry with each dump of the seed into a mixing chamber for complete blending.

The liquid treaters are the most recent developments in the treatment industry. Their claim to fame lies in their method of applying undiluted liquid formulations directly to the seed. Their success, in part, may be attributed to the volatile action of the liquid mercurials which they apply wherein complete seed coverage is not necessary. The action of the liquid treater is similar to the slurry in that accurate treatment is maintained through synchronization of a metering cup and a specified seed dump.

Can seed treatment be justified? Truthfully, I can pass on to you only what I've read. Unfortunately, I've never planted an acre of anything for a living. You folks that have known better than I whether seed treatment really pays - but I'm seriously inclined to think that it does because here is what the authoritative people say about the subject:

Seed treatments are effective in controlling many seed-borne diseases - the so-called systemic diseases where the seed becomes infested during harvest or storage and the developing seedling becomes infected. Here, treatment is completely effective against such systemics as bunt of wheat, loose and covered kernel smuts, loose and covered smuts of oats and other disastrous diseases of small grains and cotton.

Those systemic diseases which infect the plant during flowering and later become established within the seed to be manifested in the next generations growing plant are not effectively controlled by chemical treatments, that is, until recently! I do understand that a new treatment formulation is effective for loose smut. Until this breakthrough, only hot water treatments were effective for loose smuts of barley and wheat.

Seed treatments also control the seed-borne phase of the so-called non-systemic diseases which infest the seed during harvest or storage, and following planting the fungus attacks the seed and/or seedling, killing it prior to emergence or producing a blighted plant which spreads the disease. Chemical seed treatments control these helminthosporium spots, blights of barley, oats, rye and many other blight and rust diseases.

Those who know or who have had experience also say that seed should be treated to protect seeds against seed rot and seedling blights. Seed treatment, by its protective coating around the seed, acts as a barrier from both seed-borne and soil-borne organisms. Depending upon the crop, the effects from such diseases may be seed rot, pre-emergence damping-off, seedling blight, damping off and others.

Although it is not normally considered that germination per se of a given lot of seed can be improved by seed treatments, it may be said that through the control of surface molds, particularly in the standard germination test, seed treatments will improve germination. Treatments may also hold in check certain damaging molds during storage periods which otherwise might adversely affect germination.

Ask those who know and they will also say treat for protection against storage insects. Some treatment products may possess insect repellant properties, but for complete protection, compatible insecticides are added to fungicides. The need varies with the crop seed, with location and with sanitation conditions.

Finally, successful practice tells us to use combination treatments for controlling soil insects. A combination insecticide-fungicide gives limited protection to the seed and seedling against soil insects such as the wire worm or the seed corn maggot. Soil application may be advisable rather than seed application.

In general, mercurial treatments are recommended for small grains, flax and cotton while the non-mercurials are recommended for all other seeds. Here, a word to the wise may be sufficient - proper treating rate with mercurials is critical - over treatment may result in seed injury while undertreatment may result in failure to get effective disease control. On the other hand, non-mercurials have a wide margin of safety . In addition there are other important considerations when selecting seed treatments.

Treatment materials are formulated for various types of treaters - or maybe treaters are designed and built for specific formulations - whatever, be sure to select the proper one for the treater, either dust, slurry or liquid. A seed treatment which volatilizes (vaporizes) readily is desirable for those diseases where penetration by the treatment is necessary for effective kill.

For complete effective disease control, it is important to attain complete seed coverage with the treatment material. This is accomplished either by initial treatment distribution or redistribution of the treatment through proper treating methods.

Some seed treatments are selected because of the color they impart to the treated seed. Besides being a federal requirement, some seedsmen may use color to identify their seed. Sometimes the selection of a treating material is based upon its "one-shot" treating ability, that is, a combination fungicide, insecticide, nutrient and a bacterial inoculum. This becomes possible through the physical, biological and chemical compatibilities of all the materials in question.

Finally, a few general considerations in the area of seed treatment. Store treated seed, particularly those treated with mercurials, with care. Avoid high temperature and humidity. Treatment rate is very critical when using mercury, and mechanically injured seed are more susceptible to the injurious action of treatments. Do not store mercury treated seed in air tight storage conditions. In the case of any suspected seed injury from seed treatment, evaluate by sand or soil plantings together with standard laboratory tests.

Treated seed should be labeled properly according to both state and federal requirements, if possible. And, to assist in identifying treated seed, either visually inspect with proper equipment or use the agar plate bioassay method.

Does seed treatment really pay - sure it does! Would you venture into a yellow fever area without the preventive inoculation?

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Clipper, Model M-2B	A. T. Ferrell and Company 1621 Wheeler Street Saginaw, Michigan
Crippen, Model H-534-A Model NW-334	Crippen Manufacturing Co. Alma, Michigan
Vac-A-Way, Farm Model	J. W. Hance Mfg. Co. 235 E. Broadway Westerville, Ohio

Aspirator

Pneumatic Separator	Mandrel Industires Electric Sorting Machine Div. 6909 Southwest Freeway Box 36306 Houston, Texas

Blender

Ross TRH 1/4 size Ultra Rapid Turbo Square Mixer	Ross Machine & Mill Supply 12 N. E. 28th Oklahoma City, Oklahoma

Buckhorn Separator

Sutton, Steele and Steele	Sutton, Steele and Steele, Inc. 1031 South Haskell Dallas 23, Texas

Color Separators

Mandrel, Model Selexo	Mandrel Industires Electric Sorting Machine Div. 6909 Southwest Freeway Box 36306 Houston, Texas

Conveyors

Burrows Belt Conveyor Model R-13-3/4 HE	Burrows Equipment Company 1316 Sherman Avenue Evanston, Illinois
Carter-Day Vibrating Conveyor	Carter Day Company 655 19th Ave. N.E. Minneapolis, Minnesota
Clipper Vibrating Conveyor	A. T. Ferrell & Company 1621 Wheeler Street Saginaw, Michigan
Universal Belt Converyor Model H-2	Universal, Incorporated 245 South Washington Hudson, Iowa

Debearder

Clipper	A. T. Ferrell & Company 1621 Wheeler Street Saginaw, Michigan

Dehumidifiers

Dryomatic, Model 105	Dryomatic Division of Logetronics 7001 Loisdale Road Sprinfield, Va. 22150
Una-dyn, Model A30LT	Universal Dynamics Corp. 120 Belmont Road Woodbridge, Va. 22191

Electrostatic Separator

Carpco, Model HL118	Carpco Research & Eng. Co. 4120 Haines Street P. O. Box 3272 Jacksonville, Florida

Elevators

Burrows Bucket Type, Model 50	Burrows Equipment Company 1316 Sherman Avenue Evanston, Illinois
Clipper "Series 100"	A. T. Ferrell & Company 1621 Wheeler Street Saginaw, Michigan
Gordonbilt Airlift, 1-H.P.	Gordon Machinery Corp. P. O. Box 1452 Maryville, California
John F. Grisez	John F. Grisez Company Crows Landing, California
Lift Master Airlift, 2-H.P.	Holzinger Brothers 10140 South Shoemaker Ave. Santa Fe Springs, California
Mitchell 3-compartment Bucket type	J. L. Mitchell 2268 North Oxnard Blvd. Box 1069 Oxnard, California
Seedburo Bucket Type Model 200	Seedburo Equipment Company 618 West Jackson Blvd. Chicago, Illinois
Universal Bucket Type Model B2	Universal, Incorporated 245 South Washington Hudson, Iowa

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Universal Bucket Type Model C2	Universal, Incorporated 245 South Washington Hudson, Iowa

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Forsberg, Model 40-V	Forsberg, Incorporated Thief River Falls, Minnesota
Oliver, Model Hi-Cap 50	Oliver Manufacturing Co. Box 512 Rocky Ford, Colorado
Sutton, Steele & Steele Model AX-250	Sutton, Steele & Steele, Inc. 1031 South Haskell Dallas 23, Texas

Huller and Scarifiers

Clipper, Eddy-Giant	A. T. Ferrell & Company 1621 Wheeler Street Saginaw, Michigan
Crippen, Model S	Crippen Manufacturing Co. Alma, Michigan

Length Graders

Carter Disc Separator Model 1522	Carter-Day Company 655 19th Avenue, N. E. Minneapolis, Minnesota
Carter Disc Separator Model 1547	" "
Carter Disc Separator Model 1827	" "
Hart Uni-Flow Cylinder Separator, Model 3	" "

Magnetic Separators

John F. Grisez	John F. Grisez Company Crows Landing, California

Mixers

MacLellan Batch Mixer	Burrows Equipment Company 1316 Sherman Avenue Evanston, Illinois

Roll Mills (Dodder)

Clipper, 10 rolls	A. T. Ferrell & Company 1621 Wheeler Street Saginaw, Michigan
Warsco, 8 rolls	W. A. Rice Company Jerseyville, Illinois

Scales

Apex Bagging Machine Model D-100	Burrows Equipment Company 1316 Sherman Avenue Evanston, Illinois
Fairbanks -Morse 1000# Platform Scales	" "
Fairbanks-Morse 2500# Warehouse Scales	" "
Waymatic	Waymatic Welding and Fabricating Company Fulton, Kentucky
Howe-Richardson UNIPAK	Howe-Richardson Co. Clifton, New Jersey

Scalper

Clipper, Model 1297-1	A. T. Ferrell and Company 1621 Wheeler Street Saginaw, Michigan

Seed Treaters

Gustafson Mist-O-Matic Model M100	Gustafson Manufacturing Co. 6600 S. County Road 18 Hopkins, Minnesota
Gustafson Mist-O-Matic Model M400	" "
Panogen Augomatic Model MC	Morton Chemical Company 20 North Wacker Drive Chicago, Illinois
Panogen Automatic Model US 60-C	" "

Spiral Separator

Krussow Double Spiral	Cleland Manufacturing Co. 2800 Washington Avenue, N. Minneapolis, Minnesota

Width and Thickness Grader

Carter Precision Grader Model 1VT	Carter-Day Company 655 19th Avenue, N.E. Minneapolis, Minnesota

LIST OF LABORATORY MODEL

SEED PROCESSING AND TESTING EQUIPMENT

Air and Screen Cleaner

Clipper, Office Model	A.T. Ferrell & Company 1621 Wheeler Street Saginaw, Michigan

Aspirator

Superior, Fractionating	Carter-Day Company 655 19th Avenue, N.E. Minneapolis, Minnesota

Dielectric Heater

Thermex High Frequence Unit Model CP 10 A254	Votator Division, Chemetron Box 43 Lousiville, Kentucky

Dockage Tester

Carter, Model XT 1	Carter-Day Company 655 19th Avenue, N. E. Minneapolis, Minnesota

Electrostatic Separators

Carpco, Model HP-16	Carpco Research & Eng. Co. P. O. Box 3272 4120 Haines St. Jacksonville, Florida
Coronatron	Ding's Magnetic Separator 4740 West Electric Ave. Milwaukee, Wisconsin

Gravity Tables

Forsberg	Forsberg, Incorporated Thief River Falls, Minnesota

Gravity Tables (cont'd)

Sutton, Steele & Steele Model V-135A	Sutton, Steele & Steele, Inc. 1031 South Haskell Dallas, Texas
Oliver Stoner	Oliver Manufacturing Co. Rocky Ford, Colorado
Kvarnmaskiner Laboratory Cleaning Plant Type KM	Aktiebolaget Kvarnmaskiner Box 7015 Malmo, Sweden

This plant consists of the following equipment:

Scourer (Huller)
Air Separator (Aspirator)
Shaking Sieve Sifter (2 Screen Cleaner)
Table Separator (Gravity Separator)
Trieur (Cylinder Separator)

Length Graders

Carter, Test Cylinder	Carter-Day Company 655 19th Avenue, N.E. Minneapolis, Minnesota
Carter, Test Disc	" "
Kvarnmaskiner, "Pedigree" Cylinder	Aktiebolaget Kvarnmaskiner P. O. Box 7015 Malmo, Sweden
Superior, Test Cylinder	Carter-Day Company 655 19th Avenue, N.E. Minneapolis, Minnesota

Magnetic Separator

Gompper-Maschinen Gesellshaft "Lilliput"	Buderich Bei Dusseldorf Grunstr 32, Postfach, Germany U.S. Distributor: Ulbeco, Incorporated 484 State Highway 17 Paramus, New Jersey

Magnetic Separator (cont'd)

Grisez	John F. Grisez Co. Crows Landing, California

Moisture Testers

Burrows Moisture Recorder	Burrows Equipment Company 1316 Sherman Avenue Evanston, Illinois
Burrows Safe-Crop	" "
Motomco Moisture Meter Model 919	Motomco, Incorporated 89 Terminal Avenue Clark, New Jersey
Steinlite Moisture Tester Model, RCT, S, G	Seedburo Equipment Company 618 West Jackson Boulevard Chicago, Illinois
Tag-Heppenstall	Western Electric Instrument Corp. 614 Frelinghuysen Avenue Newark, New York
Universal, Model EH	Burrows Equipment Company 1316 Sherman Avenue Evanston, Illinois

RollMill (Dodder)

W. A. Rice	W. A. Rice Seed Company Jerseyville, Illinois

Scarifier

Forsberg, Sample-Seed Model	Forsberg, Incoporated Thief River Falls, Minnesota

Screens

Complete set of Clipper 9"x9" Hand Screens	A. T. Ferrell & company 1621 Wheeler Street Saginaw, Michigan

Spiral Separator

Krussow Spiral — Cleland Manufacturing Co.
2800 Washington Avenue, N.
Minneapolis, Minnesota

Thresher

Head Thresher — Allen Machine Shop

Width and Thickness Grader

Carter Test Precision Grader — Carter-Day Company
655 19th Avenue, N.E.
Minneapolis, Minnesota

Vibrator Separator

Mat-Osu — Mater Machine Works
520 South 1st Street
Corvallis, Oregon

Additional equipment includes: bag holders, sewing machines, seed probes, germinators, ovens, purity boards, seed dividers, seed counters, balances, microscopes, seed sample cambinets, the Vitascope, and other laboratory equipment.

Some of this equipment was contributed by:

Burrows Equipment Company
E. L. Erickson Products
Gustafson Manufacturing Company
Paul Hattaway Company
Redhead Bagholder Corporation
Seedburo Equipment Company