BIN STORAGE OF ONIONS

Thesis for the Degree of M. S.

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Gerald Oliver Edgerly

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This is to certify that the

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BIN STORAGE OF ONIONS

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INTRODUCTION

Onions are grown in many areas scattered over the United States. Michigan ranks second among the states that produce late summer onions. Fig. 1. While it may not be one of the larger crops of the state, onion production has a recognized standing among the cash crops. There are between eight and nine thousand acres of onions grown in Michigan. From this acreage, three to five million fifty-pound sacks are harvested annually. Approximately fifty per cent of the crop is put into storage.

It has been common practice to store onions in bushel crates. With a bushel of onions weighing approximately fifty pounds, it can readily be seen that the storage of onions would necessitate a tremendous number of crates - one and one-half to two million in Michigan alone.

These late summer onions are usually harvested about the middle of September or first of October. The onions are pulled and topped either by hand or machine and put into bushel crates which are placed in small stacks in the field. The onions are thus left in the field for a week or two to allow them to cure prior to being placed in storage or sold. In the storage the onions are kept cool and dry by proper circulation of the air. Cooling is accomplished by taking in the cool night air and closing all outside openings during the day until along late in the fall and early spring when the air is naturally cool most of the time. In climate such as that in Michigan, it is necessary to have the storage insulated to prevent freezing of the onions during the severe winter months.

In recent years some of the onion growers have shown interest

Fig. 1 Onions Ready for Harvest.

in the possibility of storing onions in bins. This concept of storing onions involves some quite extensive and costly changes in equipment. Before building a new storage or converting an old one to this method of bin storage, the grower would naturally want to know the most effective way to arrange his building and equipment. There are very few, if any, scientific solutions to the problems connected with bin storage of onions. Thus it is highly desirable to try to solve these problems by means of a research project.

PROBLEM

There is a question in the minds of some onion growers as to whether onions will withstand the mechanical handling that is involved in the bin storage system. Will bin storage maintain or possibly improve the quality?

The large number of crates that a grower needs for storing onions by methods used heretofore represent a substantial investment. This would amount to between two and three million dollars for Michigan growers alone. In addition to the cost of purchasing these crates, there is the cost of keeping these crates repaired and in usable condition. For some of the larger growers, this item amounts to a full time job for one or two men. Can the onion grower make more money in the long run by investing in a bin storage system and thus reduce his labor and maintenance costs?

REASONS FOR THE STUDY

The storage of onions in bins is a comparatively new concept and very little, if any scientific information is available. It is believed that considerable time and expense can be saved by storing onions by this method compared to previous methods. This project was undertaken to gather and evaluate information vital to the proper design and facilities for the satisfactory storage of onions in bins.

POINTS INVESTIGATED

The work on the project was divided into the following phases:

1. Improvement of equipment for smoother operation of placing onions in the bins.
2. Study of the effect of harvest procedure on the storage quality of onions stored in bins.
3. The determination of the necessary rate of air circulation through onions as they are stored in bins.
4. The improvement of automatic control of air circulation.

REVIEW OF LITERATURE AND PREVIOUS WORK

The ability of onions to keep well in storage, irrespective of the method of storing, is to a great extent dependent upon the condition of the onions prior to placing them in storage. Hoyle,[3] in his work on stage of maturity and length of topping as these factors affect the breakdown of onions in storage, points out some interesting findings. Onions with green tops were found to have the most shrinkage and the highest losses due to spoilage in storage. Those with the tops dried down kept the best and had the least shrinkage. The onions with the shortest tops (no tops up to one inch) generally showed the least rot and total loss. He also found that the length of the top had little effect if the top was dried down. This tends to bear out the results of this project in connection with onions stored with the dried tops on.

The type and amount of curing prior to storage is another factor which has its effect on the ability of onions to keep in storage. Mr. Hoyle[4] also made a comparative study of artificially cured, field cured, and non-cured onions as to their consequent result on storage losses. He made his comparisons on the following six treatments:

1. Onion bulbs alone - no curing.
2. Onion bulbs alone - field cured in burlap bags.
3. Onion bulbs alone - artificially cured in bags, heated to between 105 and 118° F.
4. Same as No. 1 plus a few tops.
5. Same as No. 2 plus a few tops.
6. Same as No. 3 plus a few tops.

After one month in storage all treatments were checked. The results from the least to the most rot were in this order: 6, 3, 1, 2, 5, 4, with treatment No. 6 being significantly better than all other treatments excepting treatment No. 3.

Mr. Hoyle came to these conclusions:

1. Moisture loss was the greatest where rotting was severe.
2. Field curing in burlap bags was generally unsatisfactory.
3. For storage, onions should be free as possible from bruises, cuts, and green material.
4. Bulbs with green material mixed among them stored well after artificial curing, but quickly decayed

if field cured or not cured.

5. In all the experiments conducted, the artificial curing saved much time and was highly satisfactory.

6. No bulbs showed heat injury from the artificial curing. The heating was done to remove excess moisture which is conducive to decay.

Even though the onions may be properly matured and cured, they will not keep satisfactorily unless storage conditions are at or at least near optimum. Wright,[9] Lauritzen, and Whiteman in their work with storage temperatures and humidities, report that sprouting increases with higher storage temperature. They point out further that the relative humidity has very little effect on sprouting. However, rotting increased with an increase in relative humidity but showed little response to increased temperature.

Cleaver,[1] in his work on storage conditions in Indiana reported that in storages on which he kept data, the grower whose storage temperature averaged the warmest had 700 per cent more loss than the grower whose average storage temperature was the coolest. Losses were always higher in storages that had warmer average temperature. These losses were due principally to sprouting which in turn is induced by high temperatures. He considered relative humidity important but second to low temperature. He also stressed the importance of proper attention to storage management during the last half of the storage period. (January 1 to March 1).

It has been determined that most ideal storage conditions for onions are a temperature of 32° F. (onions freeze at about 29° F.) and relative humidity of 70 to 75%. In an effort to approach and, if possible, maintain these ideal conditions, most growers use natural or more often forced ventilation. Depending on the section of the country, these methods of ventilation have limitations obviously due to climate in being able to approach the desired 32° F. temperature. The usual procedure for cooling by ventilation during that part of the storage period when the outside air does not remain at or below 32° F. is to take into the storage the cooler night air and closing all outside openings during the warmer part of the day. Due to fluctuations in temperature, it is highly desirable to have the ventilation system, that is the intake fan and outlets and inlets, automatically controlled by means of thermostats.

Automatic controls of this type were used by Truscott,[7] Franklin, and Gilliat in the study of automatic ventilation for common storages at the Ontario Agricultural College. They report that they were able to maintain average storage temperatures six degrees below outside temperature. Working with two storages, one cinder block and the other frame construction, they were able to maintain, with the aid of an electrical heating element, a 32° F. temperature from November 10 to April 1 for a period of twenty years. Their tests were made with the storages empty to allow for maximum fluctuation of temperature.

It is probable that these results could be closely approached, if not attained, in the onion growing areas of Michigan and other northern states. In areas farther south, it would indeed be difficult due to the previously mentioned climatic differences.

The idea of storing onions in bins is comparatively new and the author was unable to find many references to work that has been done in connection with this method of storage. However, Mr. Witzel,[8] after designing and observing the operation of a large storage in Wisconsin for three years, recommended some significant changes. These changes were to revise from sack storage to bin storage with the use of conveyors and elevators for placing the onions in and removing them from the storage. He also recommended the use of forced air circulation and refrigeration in order that the onions could be put into storage early without excessive sprouting.

Mr. Fitch[2] had had considerable experience with onion storages and his compilation of material herein referred to is based on the actual experiences of Mr. Fitch and the people for whom he has designed storages and others whose storage practices and operations he has observed. He has built several storages in Iowa and has observed storage practices and design in the Red River Valley, New York, Illinois, Wisconsin, Iowa, and Michigan. Sketches and comments are presented as a basis for design whereby the prospective storage builder can proceed to construct a satisfactory onion storage facility.

Inasmuch as the design of the storage itself is not of prime importance in the portion of the project herein reported, the author will not elaborate beyond stating that proper design is important. Mr. Fitch's points about curing and storage temperatures are quite in agreement with previously cited material. Other points that Mr. Fitch makes are quite in line with the author's thinking as to possible improvements for succeeding work on this project.

This project on bin storage, the second year of which is the subject of this thesis, was originated prior to the 1949 onion harvest season. Mr. Lester Whitney conducted the work during the first year of the project. His work dealt chiefly with the design and installation of the bins, elevator, conveyors, fan and air distribution, the placing of the onions in the bins, and the removal at the end of the storage period.

The apparent success of Mr. Whitney's efforts resulted in some Michigan onion growers using the bin storage system this past season .

METHOD OF PROCEDURE

Changes in Equipment

Certain alterations of equipment in connection with this project were deemed advisable with due regard for the ability of Mr. Whitney in his design and subsequent operation of this equipment during the previous season. The seasonal nature of the work on a project of this type and the necessity of observing the equipment during the limited operation in order to determine what changes are needed to improve the function of said equipment, makes it necessary to incorporate such improvements in the succeeding season of operation. The author recognizes the fact that it is usually easier to make improvements on basic designs than to make these basic designs and have them function properly from the beginning.

This project was located at the College Muck Farm about twelve miles northeast of East Lansing, Michigan. Fig. 2. The onions were grown on the project location. After being topped and put in crates in the field, the onions were brought to the storage by truck. The truck backed onto the drive floor to where the onions in the crates could be dumped from the truck into the hopper of the elevator. Fig. 3 and 4. The elevator placed the onions on a conveyor above the bins from which the onions were diverted into the bins via a canvas chute. Fig. 5, 6, and 7. The onions were removed from the bins after storage by removing removable slats in the bottom of the bins which allowed the onions to be brought again to the drive floor by another conveyor. Fig. 8.

To improve the operation of the elevator, which was running too fast and throwing the onions off the upper end, a jack-shaft was employed to reduce the motion to one-half the former speed. Fig. 9. Additional flights, one between those previously used, were incorporated to maintain the original capacity. Fig. 3.

The canvas chute, by which the onions were lowered from the conveyor to bin, was formerly of one piece and awkward to handle as the level of the onions rose. In an effort to facilitate easier manipulation, the chute was made into four detachable sections about two feet in length. These could be readily unsnapped from the above section as the height of the onions increased within the bin.

The method of measuring the air flow through the onions of the various bins by means of differential pressures between the plenum chamber and the space underneath the bin as used by Mr. Whitney had not been too satisfactory. Upon deciding that it might be better to measure the air that actually passed through the onions, plywood covers were fitted to each bin. In the center of each cover a six-inch diameter hole was cut and fitted with a short section of six-inch stove pipe to which additional pipe could be attached. Fig. 10. The velocity of the air through the length of stove pipe (about five feet from the elbow to allow for uniform flow over the cross section of the pipe) was measured with a velocimeter. The covers were not sealed as they had to be removable for observation of the

Fig. 2 Storage Building at Site of Project.

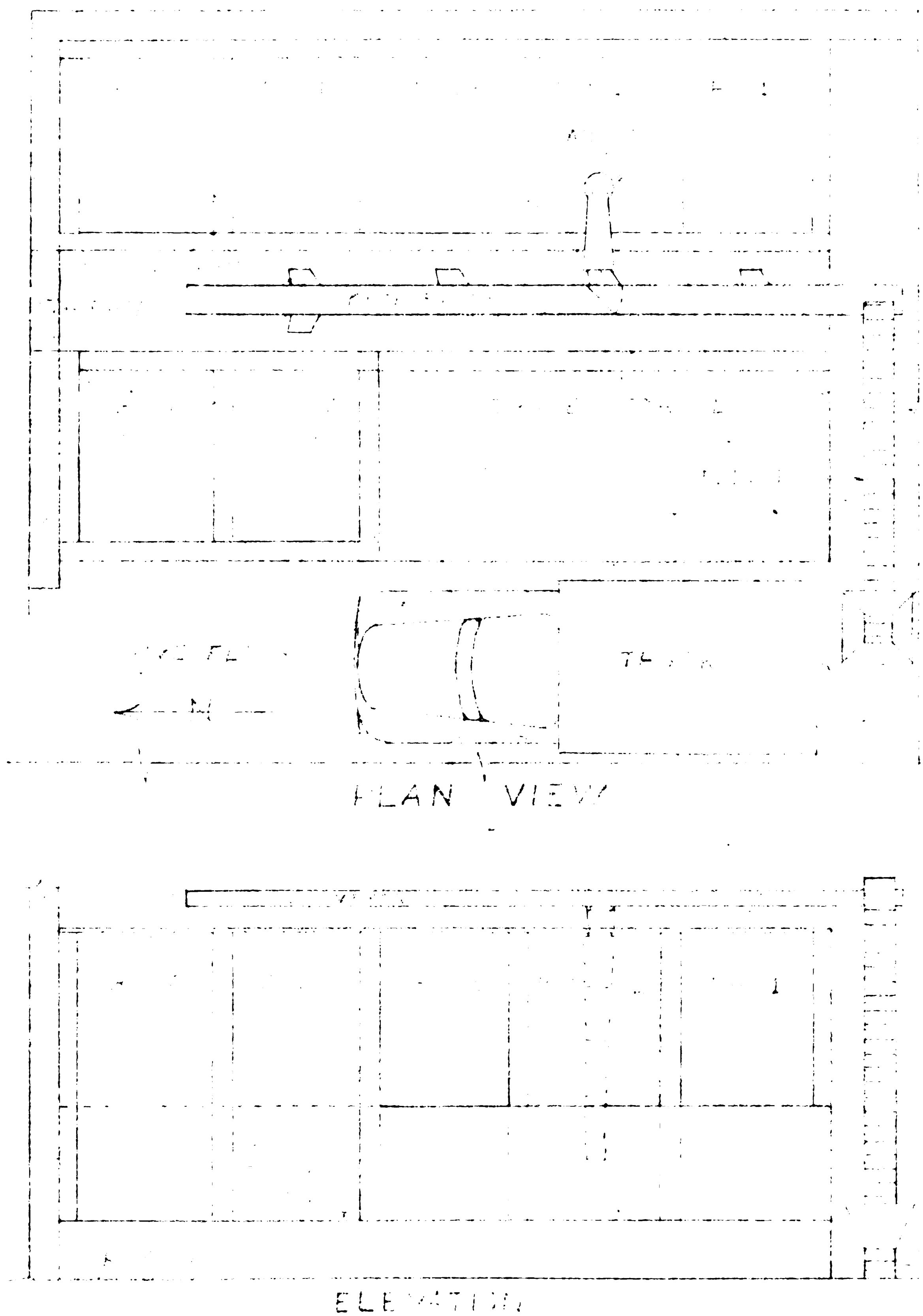

Fig. 3 Sketch of Storage Lay-out.

Fig. 4 Onions on Elevator.

Fig. 5 Onions - From Elevator to Conveyor.

Fig. 6 Onions - From Conveyor to Canvas Chute.

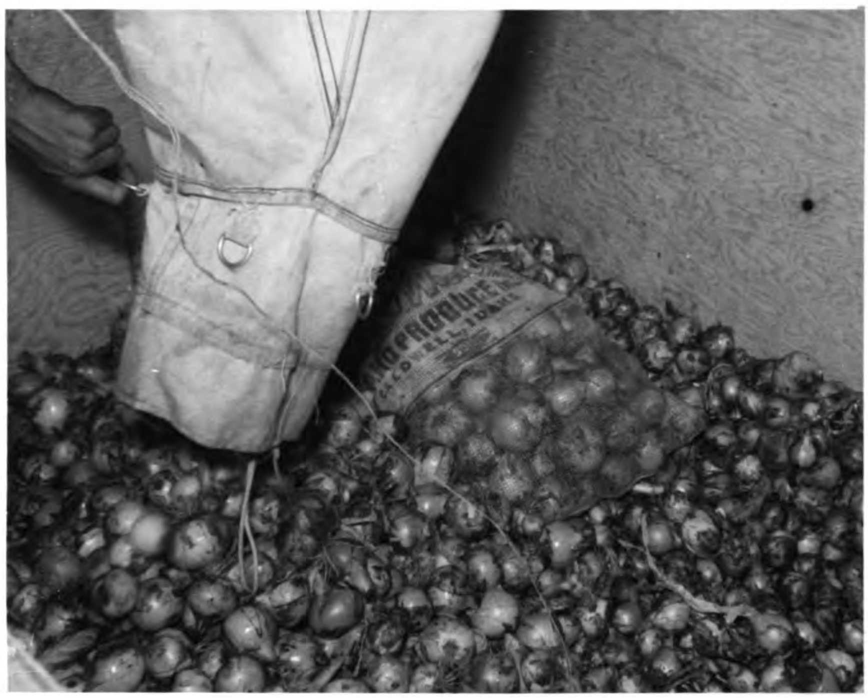

Fig. 7 Onions From Canvas Chute to Bin - Showing Placment of Check Bag.

Fig. 8 Onions Being Removed from Bin.

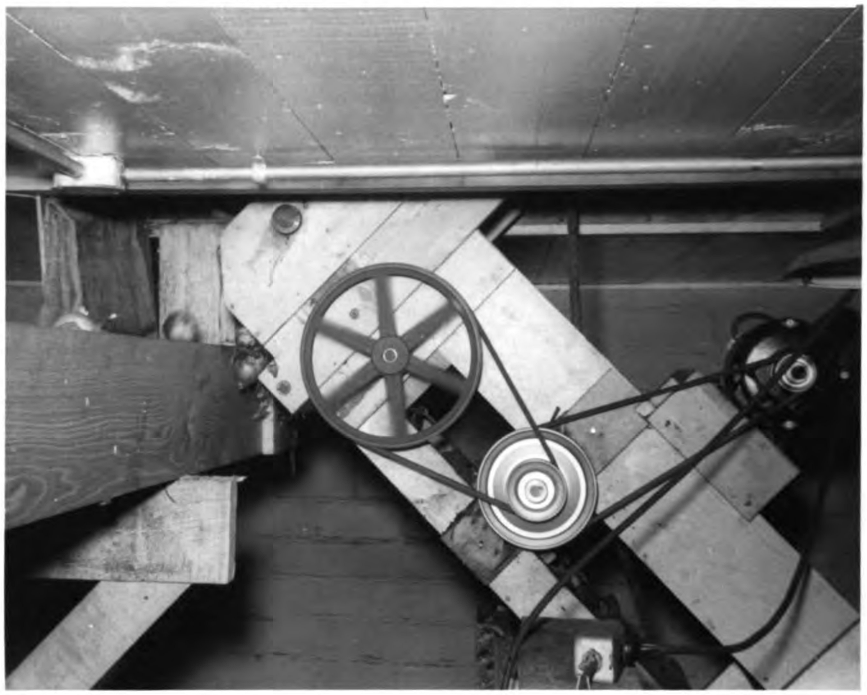

Fig. 9 Speed Reduction for Elevator.

Fig. 10 Measuring the Air Flow.

onions. However the covers were held down by weights in an effort to keep the leakage of air around the edges to a minimum. Inasmuch as test results were on a comparative basis and the leakage of each cover was approximately the same, the leakage was not considered important.

The fan for circulating the air had been so connected that it could be turned on and off either manually or automatically by means of thermostatic controls. These thermostats, one on the outside of the storage to sense the outside air temperature and one on the wall of one of the bins to sense the temperature of the air around the onions, were set to limit the fan operation to a given temperature range. This arrangement was not adequate due to the fact that the type of thermostat used in the bin was such that it had to be mounted on the wall of the bin above the onions and out of the stream of air which was directed to the outlet in the center of the cover. In an effort to correct this difficulty, another type of thermostat was procured. This thermostat, the main body of which was mounted on the outside of the bin and had a five foot capillary tube with an extended feeler bulb, which was placed near the center of the particular bin of onions.

The bulb was so placed by sliding it and the connecting capillary tube through a length of one inch pipe, which also served as protection for the tube. With the bulb at the end of the pipe, the pipe was withdrawn enough so as to leave the bulb in the air stream within the onions thus sensing the air temperature therein.

During the first part of the storage season until subfreezing temperatures occurred, the air intake for the fan was not covered.

However, it eventually became necessary to cover this opening to prevent freezing within the storage. The cover that had been built for the opening was heavy and cumbersome to handle and when it came time to use it this past season, it being made of wood, had expanded so that it did not fit. For lack of anything better at the time, this cover was used during the fore part of the winter. By mid-winter the author had alleviated the situation by installing a new fan opening cover. This cover was made of three-quarter inch plywood on the backside of which were fastened two thicknesses of three-quarter inch rigid insulation board. Within the mid-section of this cover, an electrically operated louver 28 inches square was affixed. Fig. 11. During severely cold weather, this louver could also be covered with two thicknesses of three-quarter inch rigid insulation board. Fig. 12.

It was originally planned that the louver would be actuated through the thermostatic controls for the fan and would open as the fan was turned on. However, this did not operate as the louver motor was not sufficiently powerful to open the louver against the suction of the fan. It then became necessary to open the louver before the fan was turned on. This was accomplished by having the thermostats operate the louver which in turn operated a mercury switch through a lever arrangement such that the louver was nearly wide open before the fan was turned on. Fig. 13. When the onions have thus been cooled, or the outside air has become warmer than desired for sufficient cooling, the thermostats break the louver motor circuit and the louver closes under spring tension turning off the fan.

If it is desirable during the beginning of the storage season

Fig. 11 Outside View of Louver in Fan Opening Cover.

Fig. 12 View of Cold Weather Louver Cover.

Fig. 13 Plug-in Connection with Fan Opening Cover in Position.

Mercury Switch for Fan (Upper Right)

to take in more air than is possible through the louver during this period, the cover can be removed. To facilitate the necessary changes in the wiring for automatic control of the fan operation, a system of plug-in connections has been devised. Fig. 13 and 14. These plug-in connections, three in number, have been placed accessibly at the side of the fan and each has a different type of plug to prevent the wrong connection from being made.

Putting the Onions in Storage

The general procedure was given above to orient the reader and will not be repeated here except when necessary for clarifying further details.

The onions stored in bins one, two, three, four, and five, Fig. 3 were placed therein September 7, 8, and 9, 1950. Due to rainy weather, bins six and seven were not filled until September 18 and 19, 1950. As the onions were being put into the bins, thermocouples were placed in all bins as follows: one in the air chamber under the bin, one at the three-foot level, one at the five-foot level, one at the seven-foot level, and one in the air space above the onions. To allow for an air space between the onions and the cover, the bins were filled only to the eight-foot level whereas the covers were nine and one-half feet from the bottom of the bins.

Three twenty-five pound check bags were placed in each bin as it was being filled; one at the three-foot level, one at the five-foot level, and one at the seven-foot level.

Aside from the two men dumping the onions from the crates on the truck into the hopper of the elevator, a man was stationed along the

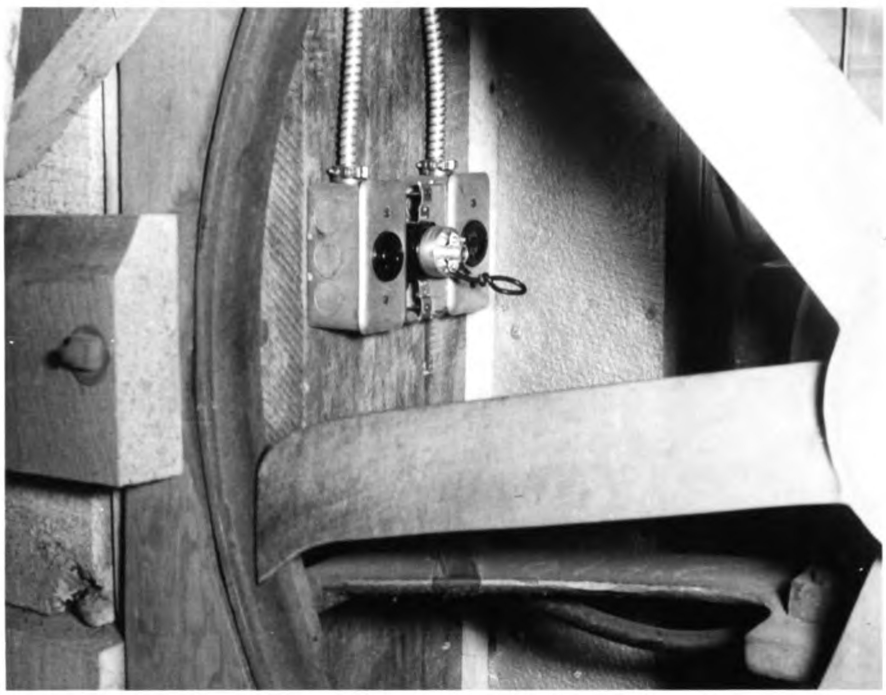

Fig. 14 Plug-in Connection with Fan Opening Cover Removed.

conveyors to insure the continuous flow of onions into the canvas chute as the onions did not always roll off the conveyor. A fourth man was stationed in the bin where he directed the flow of onions from the canvas chute, placed the thermocouples and check bags.

Harvest Procedure

The onions that were stored in bins one, two, and three were machine topped and windrowed in the field for about a week to ten days prior to storing. These three bins were filled with equal quantities of onions of the same quality and from the same area in the field.

For bin number four the onions with the tops left on were allowed to dry somewhat in the field before being put into the bin.

The onions for bin five were hand topped and left in windrows for a few days before storing.

The onions for bin six were machine topped and left in windrows in the field three or four days before being put in the bin.

For bin seven, the onions were machine topped and placed directly into the bin.

In order to compare bin storage to crate storage as previously described, eleven crate samples for each of bins four, five, six, and seven and one such sample for bins one, two, and three, were stored as is customary for crate storage.

Data Taken

With the thermocouples placed as indicated above, the temperature readings were taken and recorded. Table 1. (appendix). These readings were discontinued after it was decided that the onions were keeping and very little temperature difference occurred in the bins.

From time to time during the first three months of the storage period, the relative humidity of the air as it entered the bottom and left at the top of the bins, was checked by means of an aspiration psychrometer. Table 2. (appendix).

The rate of air flow, while the fan was running, was checked and corrected if necessary at least once a week until freezing weather made it inadvisable to run the fan and risk freezing the onions. Fig. 10. Table 3. (appendix). The rate of air flow was regulated by means of openings between the plenum chamber and the air spaces beneath the respective bins. Having had good results during the previous season with approximately one cubic foot of air per minute for each cubic foot of onions, this was the basis for the determination of the rate of flow for bins four, five, six, and seven. As the rate of air flow was the object of study for bins one, two, and three, the respective rates were different. (Calculations shown in appendix). The rate for bin one was based on one cubic foot per minute, for bin two, one-half of a cubic foot per minute, and bin three on two cubic feet per minute of cubic foot of onions.

In connection with the air flow, the static pressure within the plenum chamber was checked and adjusted by means of an adjustable opening in the end of the plenum chamber furtherest from the fan. This pressure was measured in inches of water by means of a manometer.

The actual operation of the fan, for the most part, was controlled manually. This was due to the fact that the original thermostatic control set-up did not function properly, and there was some delay in having the revised set-up wired. Therefore the operation of the fan was left to the discretion of the foreman of the Muck Farm where the project was located.

A record of the fan running time was recorded automatically by means of a recording thermometer. The feeler bulb of this thermometer was fastened to the outside of the fan motor. When the fan was turned on, the bulb would sense the added heat of the motor and this change in temperature would thus be recorded on the weekly chart of the recorder. In addition to this, the foreman kept a record of the time that he operated the fan. As it turned out, both methods had their fallacies. There were times when the air was quite cool and the flow of air over the motor would carry away the heat quickly enough so that no rise in temperature was recorded on the chart. There were also times when the recorder failed to function properly and after December 23, it would not function at all. Also the record that the foreman kept from the beginning of the storage period in September up to January 1 was lost. Therefore, the record of the running time of the fan for this period could only be approximated as taken from the record charts.

As indicated in Table 4 (appendix), part of the onions were removed from the bins, to be sorted and sold around the first part of January and every so often thereafter. It became difficult to maintain the air flow adjustments from that time on and therefore the record of the air flow rate was discontinued.

All other data was taken as the onions were removed from the bins. Table 4. This data consisted of date of removal, the weight of the good or salable onions, and the weight of those culled out due to rotting and sprouting. As the respective bins were emptied, the corresponding crate sample and check sacks were also weighed and graded. Some of the check bags rotted so that it was impossible to complete data on all of the original bags.

Bruising Tests

After the onions had been put in the bins, there was some speculation as to the merits of the canvas chute and the necessity of a man in the bins. Being unable to find any information as to the amount of bruising or the height that onions could be allowed to fall freely and not impair their salability at the end of the storage period, it was undertaken to make such information available and prove or disprove the need of the canvas chute or some similiar device.

The effect of bruising was thus tested. The test was so designed that the results could be analyzed by statistical methods. The onions used in the test were divided into three sizes, small (1 1/2 to 1 3/4 inches in diameter), medium (1 3/4 to 2 1/4 inches in diameter), and large (2 1/4 to 2 3/4 inches in diameter). Three samples of each size were dropped one at a time from heights of three, five, seven, nine and eleven feet. Three samples of each size were dropped, four at a time from a height of nine feet. The controls, three samples of each size, were not dropped. The onions were dropped into bushel crates which simulated the slated bottom in the bins and considered the most severe in so far as bruising was concerned.

After the onions were bruised on the 29th of October, they were stored under conditions similar to the onions in the bins. These bruised samples were graded on March 1st, 1951.

Supposedly, each sample was made up of 65 onions. However, in checking the results, it was found that some of the samples varied slightly. Because of this discrepancy and to make the results more meaningful and easier to analyze, the final data was put on a percentage of good onions basis. The number of salable onions and the actual number per sample were recorded from which was figured the heretofore mentioned percentage.

RESULTS

The changes that were made in the equipment prior to and during the onion storage season of 1950-51, were considered worthwhile improvements. By reducing the speed and increasing the number of flights on the elevator, the flow of the onions from the elevator was steady yet gentle enough that the onions were not bruised.

The rate of air flow could readily be read at the end of the six-inch duct which was attached to the hole in the cover of the respective bins. However, it was somewhat inconvenient when adjustments were necessary as the adjustable openings were at the bottom of the bins and thus involved climbing up and down a ladder.

It was not possible to maintain the calculated rate of air flow through bin No. 3, (two cu. ft. of air per cu. ft. of onions) even though the opening was wide open. However, it was possible to maintain a rate of air flow in this bin sufficiently higher than that for bins No. 1 and 2 with which the rate of flow was being compared. The results of this comparison are somewhat inconsistent, although bin No. 3, with the highest rate of flow, did show a slight improvement over bins No. 1 and 2. Fig. 15. Table 4. (appendix).

Due to the fact that the revised automatic control arrangement was not completely connected until well toward the end of the storage period, the merits of this arrangement could not be fully realized within the time allowed for this thesis project.

The temperatures taken during the first month of storage indicated that the onions did not heat, except for bin No. 2 at the beginning, and thus were considered to be keeping satisfactorily. However, these temperature readings together with the relative humidity data indicate that there was some excess moisture in the onions but the relative humidity of the outside air that was drawn into the bins was at times too high to remove very much, if any, of this excess.

As indicated by the storage data, the onions that were hand topped kept somewhat better than those stored with the tops left on. Fig. 15. However, both the hand topped onions and those with the tops left on kept better than the machine topped onions. There is also an indication that onions brought direct from the field kept better than those left in the field a few days before storing.

Inasmuch as the data and results of the previous season were not published or made available at the time this thesis was written, the author could only compare the results herein with verbal information from those who had observed the work of the previous season In making such a comparison, it will be sufficient to state that the

Fig. 15 Bar Graph of Storage Results.

onions kept better during the 1949-50 season than they did for the 1950-51 season. This could readily be due to factors beyond the scope of this project.

The author used statistical methods in determining the results of the bruising tests. Table 5. (appendix). An analysis of variance was made of the data on a percentage basis. The results for the small onions were inconsistent. It was found that the medium sized onions could not be dropped more than five feet without significant loss. The large onions could not be dropped more than three feet. In analyzing those onions dropped from the nine-foot height, one at a time versus four at a time, it was found that those onions dropped four at a time had a significantly higher percentage of good onions than those dropped one at a time. However, those dropped four at a time from a nine-foot height still had a significant loss when compared with the control. This would indicate that onions sustain less bruising when dropped in groups. These results show that it is necessary to use the canvas chute or some other means of breaking the free fall of the onions when there is more than a three foot drop.

CONCLUSIONS

On the basis of the results of this phase of the work on the storage of onions, the following conclusions have emanated:

1. The merits of bin storage are still in doubt.
2. Hand topped onions and onions stored with the dried tops left on the onions have the least losses in bin storage.
3. In Michigan it is nearly impossible to maintain

the desired onion storage conditions with the circulation of outside air only for a long storage period. (September to March 1).

4. Onions should not be allowed to fall freely more than three feet to the floor of the bin.

SUGGESTIONS FOR FUTURE STUDIES

Based on observations made during the course of this study, the author hereby offers the following suggestions:

1. Put baffles in the canvas chute to break the free fall of the onions.
2. Arrange to manipulate the canvas chute from the top of the bin and thereby make it unnecessary to have a man in the bin. This would alleviate the packing and possible bruising that were thought to be factors in the high per cent of spoilage in the study.
3. Use either heat or chemical to control the relative humidity or the air.
4. Give the automatic fan controls a fair test.
5. Devise an accurate method of recording the fan running time and the time of day that it is in operation.
6. Try tilting the conveyor slightly toward the bin being filled to see if onions will roll off more readily.
7. Test the bruising of onions against onions.

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APPENDIX

CALCULATION OF RATE OF AIR FLOW THROUGH BINS

Each bin had the same dimensions.

Length = 6 feet.
Width = 4.5 feet

$4.5 \times 6 = 27$ sq. ft.

Bins 1, 2, and 3 were filled with onions 9 feet deep.

$27 \times 9 = 243$ cu. ft. onions per bin.

Area of 6 inch round duct where flow was measured.

$A = Hr^2 = 3.4 \times (\frac{1}{4})^2 = .196$ sq. ft.

For Bin No. 3, the air flow was based on:

2 cu. ft. of air per minute per cu. ft. of onions.

$243 \times 2 = 486$ cu. ft. per minute.

$$\text{Velocity} = \frac{\text{VOLUME NEEDED}}{\text{Area of Duct.}}$$

$$V = \frac{486}{.196} = 2480 \text{ ft. per minute.}$$

For Bin No. 1, the air flow was based on 1 cu. ft. of air per cu. ft. of onions.

$243 \times 1 = 243$ cu. ft. per minute.

$$V = \frac{243}{.196} = 1240 \text{ ft. per minute.}$$

For Bin No. 2, the air flow was based on 1/2 cu. ft. of air per minute per cu. ft. of onions.

$243 \times 1/2 = 122$ cu. ft. per minute.

$$V = \frac{122}{.196} = 623 \text{ ft. per minute.}$$

Table 1

Temperature Data

Bin No. 1

Date and Time of Reading		Air Under Bin	3 ft. Level in Bin	5 ft. Level in Bin	7 ft. Level in Bin	Air At Top of Bin	Outside Air
Sept. 9	6:00 p.m.	68	71	65	65	64	74
10	11:00 a.m.	66	67	67	67	67	66
10	6:30 p.m.	66	68	69	69	68	66
11	11:00 a.m.	67	68	72	70	70	69
11	6:30 p.m.	66	67	73	74	70	68
12	9:00 a.m.	64.5	66	76	76	71	64
12	5:00 p.m.	62	63	75	75	70	64
13	3:30 p.m.	67.5	69	76	75	66	57
14	9:30 a.m.	54	54	56	55	54	55
15	3:30 p.m.	58	58	52	52	53	58
16	10:30 a.m.	49	50	51	50	49	60
17	9:30 p.m.	48	48	48	47	46	49
18	3:30 p.m.	57	58	46	47	50	59
20	3:00 p.m.	49	55.5	50	49	48	60
22	3:30 p.m.	55	56	53	53	53	56
24	10:45 a.m.	46	47	47	47	48	47
25	3:30 p.m.	48	48	41	41	41	50
27	2:10 p.m.	57	58	46	46	47	66
30	7:30 a.m.	55	55	59	59	57	54

Table 1

Temperature Data

Bin No. 2

Date and Time of Reading	Air Under Bin	3 ft. Level in Bin	5 ft. Level in Bin	7 ft. Level in Bin	Air At Top of Bin	Outside Air
Sept. 9 6:00 p.m.	74	74	74	71	77	74
10 11:00 a.m.	72	72	72	72	66	66
10 6:30 p.m.	73	73	73	73	68	66
11 11:00 a.m.	74	73	73	76	70	70
11 6:30 p.m.	74	74	74	76	69	68
12 9:00 a.m.	74	74	74	79	71	64
12 5:00 p.m.	72	72	72	77	69	64
13 3:30 p.m.	72	69	72	77	65	57
14 9:30 a.m.	59	58	60	62	54	55
15 3:30 p.m.	53	53	54	54	52	58
16 10:30 a.m.	52	52	53	55	50	60
17 9:30 p.m.	50	50	50	52	47	49
18 3:30 p.m.	53	54	55	46	48	59
20 3:00 p.m.	54	54	54	56	51	60
22 3:30 p.m.	53	53	53	54	52	56
24 10:45 a.m.	48	48	48	53	49	41
25 3:30 p.m.	49	49	50	45	43	50
27 2:10 p.m.	48	48	48	45	47	66
30 7:30 a.m.	58	58	58	56	55	54

Table 1

Temperature Data

Bin No. 3

Date and Time of Reading	Air Under Bin	3 ft. Level in Bin	5 ft. Level in Bin	7 ft. Level in Bin	Air At Top of Bin	Outside Air
Sept. 9 6:00 p.m.	64	67	76	73	65	73
10 11:00 a.m.	64	65	78	72	65	66
10 6:30 p.m.	65	65	79	72	65	66
11 11:00 a.m.	65	67	82	74	67	69
11 6:30 p.m.	65	65	81	74	66	68
12 9:00 a.m.	63	64	83	75	69	64
12 5:00 p.m.	62	63	81	74	66	64
13 3:30 p.m.	56	58	79	73	61	57
14 9:30 a.m.	53	54	56	54	54	55
15 3:30 p.m.	55	58	51	52	55	58
16 10:30 a.m.	48	50	50	49	47	60
17 9:30 p.m.	46	48	47	46	46	49
18 3:30 p.m.	55	59	46.5	48.5	52	59
20 3:00 p.m.	53	56	50	49	47	60
22 3:30 p.m.	52	56	52	52	52	56
24 10:45 a.m.	42	46	48	48	48	41
25 3:30 p.m.	50	55	41	41	41	50
27 2:10 p.m.	49	54	46	48	46	66
30 7:30 a.m.	53	54	58	57	57	54

Table 1

Temperature Data

Bin No. 4

Date and Time of Reading	Air Under Bin	3 ft. Level in Bin	5 ft. Level in Bin	7 ft. Level in Bin	Air At Top of Bin	Outside Air
Sept. 9 6:00 p.m.	66	68	61	63	65	73
10 11:00 a.m.	68	68	65	69	69	66
10 6:30 p.m.	66	65	67	71	68	66
11 11:00 a.m.	66	67	71	75	72	68
11 6:30 p.m.	66	67	73	77	74	68
12 9:00 a.m.	65	65	77	83	79	64
12 5:00 p.m.	62	63	80	84	77	64
13 3:30 p.m.	55.5	57.5	88	92	75	57
14 9:30 a.m.	53	54	61	57	54	55
15 3:30 p.m.	55	58	52	52	52	58
16 10:30 a.m.	49	50	53	50	49	60
17 9:30 p. m.	47	49	49	48	47	49
18 3:30 p.m.	51.5	56	45.5	46	50	59
20 3:00 p.m.	56	60	51	49	49.5	60
22 3:30 p.m.	52	55	52	52	52	56
24 10:45 a.m.	43	47	47	46	47	41
25 3:30 p.m.	48	49	41	41	41	50
27 2:10 p.m.	55	60	46	46	49	66
30 7:30 a.m.	53	54	59	59	56	54

Table 1

Temperature Data

Bin No. 5

Date and Time of Reading	Air Under Bin	3 ft. Level in Bin	5 ft. Level in Bin	7 ft. Level in Bin	Air At Top of Bin	Outside Air
Sept. 9 6:00 p.m.	68	68	61	61	62	73
10 11:00 a.m.	63	63	62	64	64	66
10 6:30 p.m.	66	66	63	65	65	66
11 11:00 a.m.	66	66	64	65	66	68
11 6:30 p.m.	65	65	65	66	66	68
12 9:00 a.m.	63.5	64	66	67	67	64
12 5:00 p. m.	62	62	65	66	66	64
13 3:30 p.m.	56	56	66	66	63	57
14 9:30 a.m.	53	53	56	55	54	55
15 3:30 p.m.	55	55	51	51	52	58
16 10:30 a.m.	48	48	51	50	50	60
17 9:30 p.m.	47	47	49	48	47	49
18 3:30 p.m.	54	54.5	45	45.5	46.5	59
20 3:00 p.m.	55	55	49.5	49.5	49.5	60
22 3:30 p. m.	52	52	51	51	52	56
24 10: 45 a.m.	44	44	50	49	48	41
25 3:30 p.m.	48	48	43	42	41	50
27 2:10 p.m.	52	52	45	46	46	66
30 7:30 a.m.	53	53	56	56	57	54

Table 1

Temperature Data

Bin No. 6

Date and Time of Reading	Air Under Bin	3 ft. Level in Bin	5 ft. Level in Bin	7 ft. Level in Bin	Air At Top of Bin	Outside Air
Sept. 17 9:30 p.m.	45	45	44	48	48	49
20 3:00 p.m.	51	51	49.5	51	51	60
22 3:30 p.m.	51	51	50	51	52	56
24 10:45 a.m.	48	49	49	44	45	47
25 3:30 p.m.	43	43	43	47	44	50
27 2:10 p.m.	45	45	45	51	52	66
30 7:30 a.m.	56	56	56	55	54	54

Bin No. 7

Date and Time of Reading	Air Under Bin	3 ft. Level in Bin	5 ft. Level in Bin	7 ft. Level in Bin	Air At Top of Bin	Outside Air
Sept. 20 3:00 p.m.	49	46	47	46.5	46.5	60
22 3:30 p.m.	52	50	50	50	50	56
24 10:45 a.m.	48	48	47	48	48	41
25 3:30 p.m.	42	41	42	42	42	50
27 2:10 p.m.	52	49	45	45	47	66
30 7:30 a.m.	55	57	57	56	57	54

Table 2

Relative Humidity Data

Bin No. 1

Date of Reading	Air Going Into Bin D. B.	W. B.	R. H.	Air Coming Out Of Bin D. B.	W. B.	R. H.
Sept. 14	61	59	90%	61	60	95%
Sept. 15	65	59	70%	60	58	90%
Sept. 17	54	50	75%	53.5	51.5	87%
Sept. 20	68	60	64%	59.5	57	85%
Sept. 22	62	57	74%	59	58	94%
Sept. 27	66	56	53%	58	53	72%
Sept. 30	60.5	58	85%	64	64	94%
Oct. 4	55	49	65%	54	50	75%
Oct. 7	59	53	69%	53	51	88%
Oct. 12	52.5	48	72%	53	52	93%

Bin No. 2

Date of Reading	Air Going Into Bin D. B.	W. B.	R. H.	Air Coming Out Of Bin D. B.	W. B.	R. H.
Sept. 14	61	59	90%	63	62	94%
Sept. 15	65	59	70%	60	60	100%
Sept. 17	54	50	75%	53.5	51.5	85%
Sept. 20	68	60	64%	60.5	59	92%
Sept. 22	62	57	74%	59.5	58.5	95%
Sept. 27	66	56	53%	55	52	82%
Sept. 30	60.5	58	85%	63	62	94%
Oct. 4	55	49	65%	52	50	88%
Oct. 7	59	53	69%	53.5	51.5	85%
Oct. 12	52.5	48	72%	53.5	53	96%

Table 2

Relative Humidity Data

Bin No. 3

Date of Reading	Air Going Into Bin D. B.	W. B.	R. H.	Air Coming Out Of Bin D. B.	W. B.	R. H.
Sept. 14	61	59	90%	61	59	90%
Sept. 15	65	59	70%	62	59	85%
Sept. 17	54	50	75%	53	51	88%
Sept. 20	68	60	64%	60.5	57.5	84%
Sept. 22	62	57	74%	58	57.5	98%
Sept. 27	66	56	53%	55	52	82%
Sept. 30	60.5	58	85%	63.5	61.5	90%
Oct. 4	55	49	65%	50	45	68%
Oct. 7	59	53	69%	51.5	49.5	86%
Oct. 12	52.5	48	72%	53	51.5	91%

Bin No. 4

Date of Reading	Air Going Into Bin D. B.	W. B.	R. H.	Air Coming Out Of Bin D. B.	W. B.	R. H.
Sept. 14	61	59	90%	62	60.5	92%
Sept. 15	65	59	70%	62	59	85%
Sept. 17	54	50	75%	53.5	51	85%
Sept. 20	68	60	64%	59.5	56.5	84%
Sept. 22	62	57	74%	59	58	94%
Sept. 27	66	56	53%	55	52	82%
Sept. 30	60.5	58	85%	63.5	61.5	90%
Oct. 4	55	49	65%	50	46	75%
Oct. 7	59	53	68%	52.5	49	78%
Oct. 12	52.5	48	72%	53	51	88%

Table 2

Relative Humidity Data

Bin No. 5

Date of Reading	Air Going Into Bin			Air Coming Out Of Bin		
	D. B.	W. B.	R. H.	D. B.	W. B.	R. H.
Sept. 14	61	59	90%	61	59	89%
Sept. 15	65	59	70%	62	59	84%
Sept. 17	54	50	75%	53.5	51	85%
Sept. 20	68	60	64%	61	57	78%
Sept. 22	62	57	74%	58.5	56.5	89%
Sept. 27	66	56	53%	55	52	82%
Sept. 30	60.5	58	85%	63.5	61	87%
Oct. 4	55	49	65%	50	45	68%
Oct. 7	59	53	69%	52.5	49.5	81%
Oct. 12	52.5	48	72%	53	51	88%

Bin No. 6

Date of Reading	Air Going Into Bin			Air Coming Out Of Bin		
	D. B.	W. B.	R. H.	D. B.	W. B.	R. H.
Sept. 17	54	50	75%	53.5	51	85%
Sept. 20	68	60	64%	59.5	58	92%
Sept. 22	62	57	74%	60.5	58.5	89%
Sept. 27	66	56	53%	56	52	78%
Sept. 30	60.5	58	85%	63.5	61.5	89%
Oct. 4	55	49	65%	50.5	48	83%
Oct. 7	59	53	69%	52.5	50.5	87%
Oct. 12	52.5	48	72%	53	52	93%

Bin No. 7

Date of Reading	Air Going Into Bin			Air Coming Out Of Bin		
	D. B.	W. B.	R. H.	D. B.	W. B.	R. H.
Sept. 20	68	60	64%	58	56.5	92%
Sept. 22	62	57	74%	59	58	95%
Sept. 27	66	56	53%	56	52	77%
Sept. 30	60.5	58	85%	64	62	90%
Oct. 4	55	49	65%	51	49	87%
Oct. 7	59	53	69%	52	50.5	90%
Oct. 12	52.5	48	72%	53	51.5	91%

Table 3

Air Flow Data

Flow in Feet Per Minute Through a Six-Inch Duct. (Fig. 10)

Date	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6	Bin 7	Static Press. in Plenum In. of H_2O
+Sept. 13	1308	756	1764	1140	1152			
Sept. 20	1175	650	1550	1170	1150	820	850	
Sept. 27	1125	925	2600	2200	1750	1375	1375	.74
*	1190	950	2500	1800	1800	1350	1350	.94
Sept. 30	1125	1000	2600	1750	1850	1500	1375	.97
*	1250			1200	1200	1200	1200	1.02
Oct. 4	650	625	1575	1075	1100	910	875	1.05
*	1200	800	1500	1125	1125	1250	1250	.95
Oct. 7	1200	800	1500	1100	1100	1225	1250	.91
Oct. 12	1200	800	1520	1150	1175	1275	1325	.91
*					1150	1250	1250	.88
Oct. 19	1200	820	1475	1100	1150	1200	1225	.90
Oct. 30	1100	700	1200	400	950	1100	1150	.71
*	1225	825	1500	1175	1160	1300	1300	1.01
Nov. 8	1325	850	1550	1200	1200	1375	1300	1.0
*	1250					1325	1325	1.04
Nov. 15	1250	825	1500	1150	1100	1250	1275	.98
*					1150		1250	
Dec. 2	1225	600	1460	1150	1125	1200	1210	.95
*		825			1150			
Aver.	1256	836	1885	1321	1305	1230	1230	.93
#Aver. C.F.M.	246	164	370	259	256	241	241	

+Previous air flow rate calculated erroneously.

*Adjusted to these readings.

#For approximately 60 to 75 hours of fan running time.

Table 4

Storage Data and Results

Bin No. 1

Date of Removal		Good Onions Pounds	Cull Onions Pounds	Per Cent of Good Onions
Jan. 3		500	353.5	58
Jan. 12		707	615	53
Feb. 5*		2658.5	2742.25	49
	Total	3865.5	3710.75	51

Check Bags

Check bags rotted - - data and results unobtainable.

Crates

Original Weight was 543 pounds. (11 crates).
2 crates were lost in moving into storage from outside.
9/11 x 543 = 444 pounds (as basis for original weight for remaining 9 crates).

Date Checked	Good Onions Pounds	Seconds Pounds	Cull Pounds	Per Cent Good	Per Cent Shrink
Feb. 13	225	13	109.25	65	22

Bin No. 2

Date of Removal		Good Onions Pounds	Cull Onions Pounds	Per Cent of Good Onions
Jan. 3		445	273	62
Jan. 12		1066	791.75	57
Feb. 5*		2792.5	2109	57
	Total	4303.5	3173.75	58

Check Bags

Check bags rotted - - data and results unobtainable.

Crates

(See crates under Bin No. 1).

* Bin cleaned out.

Table 4

Storage Data and Results

Bin No. 3

Date of Removal	Good Onions Pounds	Cull Onions Pounds	Per Cent of Good Onions
Jan. 10	1610	1177.25	58
Jan. 22	1315	854.75	61
Feb. 13*	1826.25	910.	67
Total	4751.25	2942	62

Check Bags

Original weight was 25 pounds per bag.

Date Checked	Final Bag Wt. Pounds	Good Onions Pounds	Per Cent Good	Per Cent Shrink
Feb. 13	19	12.75	67	0[1]
Feb. 13	23.5	21	89	6
Feb. 13	22.75	18	79	9

Crates
(See crates under Bin No. 1)

Bin No. 4

Date of Removal	Good Onions Pounds	Cull Onions Pounds	Per Cent of Good Onions
Jan. 25	1143	60	95
Mar. 22, 23*	-	-	-
Apr. 10 (weighed)	3302	1411	70
Total	4445	1471	75

Check Bags
(No bags were placed in this bin)

Crates

Date Checked	Good Onions Pounds	Seconds Pounds	Cull Pounds	Per Cent Good	Per Cent Shrink
Apr. 10	338	2.5	86	79	22.5

Original weight was 550 pounds. (13 crates).

* Bin cleaned out.
1 Bag had a hole in it - not sure of shrinkage.

Table 4

Storage Data and Results

Bin No. 5

Date of Removal	Good Onions Pounds	Cull Onions Pounds	Per Cent of Good Onions
Dec. 30	3514	478.5	88
Jan. 3	1220	276.0	82
Mar. 15*	-	-	-
Apr. 3 (weighed)	1683.5	635.0	73
Total	6417.5	1389.5	82

Check Bags

Original weight was 25 pounds per bag.

Date Checked	Final Bag Wt. Pounds	Good Onions Pounds	Per Cent Good	Per Cent Shrink
Mar. 15	18.5	10	54	0[1]
Mar. 15	20.75	14.5	70	17

Third bag rotted - data and results unobtainable.

Crates

Original weight was 514.5 pounds. (11 crates).

Date Checked	Good Onions Pounds	Seconds Pounds	Culls Pounds	Per Cent Good	Per Cent Shrink
Apr. 3	301	2.75	131	69	16

* Bin cleaned out.

1 Bag had a hole in it - not sure of shrinkage.

Table 4

Storage Data and Results

Bin No. 6

Date of Removal		Good Onions Pounds	Cull Onions Pounds	Per Cent of Good Onions
Jan. 6		2428	1334.5	64
Mar. 6*		2478	1944.5	56
	Total	4906	4279	53

Check Bags

Original weight was 25 pounds per bag.

Date Checked	Final Bag Wt. Pounds	Good Onions Pounds	Per Cent Good	Per Cent Shrink
Mar. 14	21	6.25	30	16
Mar. 14	22.5	14.25	63	10

Third bag rotted - data and results unobtainable.

Crates

Original weight was 558.5 pounds. (11 crates).

Date Checked	Good Onions Pounds	Seconds Pounds	Culls Pounds	Per Cent Good	Per Cent Shrink
Mar. 14	296	5	164	64	17

* Bin cleaned out.

Table 4

Storage Data and Results

Bin No. 7

Date of Removal		Good Onions Pounds	Cull Onions Pounds	Per Cent of Good Onions
Jan. 3		1750	1395.5	56
Jan. 13		1350	710	66
Mar. 4*		1904	1071.5	64
	Total	5004	3177	61

Check bags

Original weight was 25 pounds per bag.

Date Checked	Final Bag Wt. Pounds	Good Onions Pounds	Per Cent Good	Per Cent Shrink
Mar. 4	18	8.25	46	28
Mar. 4	22	12.25	56	12
Mar. 4	20	9.25	46	20

Crates

Original weight was 547 pounds. (11 crates).

Date Checked	Good Onions Pounds	Seconds Pounds	Cull Pounds	Per Cent Good	Per Cent Shrink
Mar. 4	268	7.5	17.25	60	18

* Bin cleaned out.

Table 5

Bruising Test Data

		Height of Drop																			
	Repli-	0 feet*			3 feet			5 feet			7 feet			9 feet			11 feet			9 feet **		
Size	cation	Spl.	Gd.	%	Spl.	Gd.	%	Spl.	Gd.	%	Spl.	Gd.	%	Spl.	Gd.	%	Spl.	Gd.	%	Spl.	Gd.	%
	1	65	27	42	65	36	55	65	22	34	65	26	40	65	24	37	65	23	35	65	37	57
Small	2	65	31	48	65	34	52	65	24	37	65	31	48	65	27	42	65	32	49	65	35	54
	3	64	31	48	65	36	55	65	29	45	65	42	65	65	27	42	65	27	42	66	33	50
	1	65	37	57	65	36	55	64	31	48	65	30	46	65	22	34	64	25	39	65	32	49
Medium	2	65	37	57	65	32	49	65	36	55	66	29	44	65	23	35	65	34	52	60	19	32
	3	65	37	57	65	35	53	66	32	48	66	28	42	66	21	32	65	22	34	65	25	38
	1	65	36	55	66	38	58	64	28	44	65	23	35	65	22	34	66	22	33	65	30	46
Large	2	65	40	62	70	25	36	66	37	56	65	33	51	65	23	35	65	26	40	65	29	45
	3	65	38	58	65	46	71	66	34	52	65	24	37	65	31	48	65	22	34	65	26	40

* Control.

** 9 feet - four at a time.

Table 5a

Per Cent of Good Onions Dropped One At a Time

Size	Replication	C	3'	5'	7'	9'	11'	Total	Aver.
				Height					
Small	1	42	55	34	40	37	35	243	40.5
	2	48	52	37	48	42	49	276	46.
	3	48	55	45	65	42	42	297	49.5
Total		138	162	116	153	121	126	816	
Average		46	54	38.7	51	40.3	42		45.3
Medium	1	57	55	48	46	34	39	279	46.5
	2	57	49	55	44	35	52	292	48.7
	3	57	53	48	42	32	34	266	44.3
Total		171	157	151	132	101	125	837	
Average		57	52.3	50.3	44	33.7	41.7		46.5
Large	1	55	58	44	35	34	33	259	43.2
	2	62	36	56	51	35	40	280	46.7
	3	58	71	52	37	48	34	300	50.
Total		175	165	152	123	117	107	839	
Average		58.3	55	50.7	41	39	35.7		46.6
TOTAL		484	484	419	408	339	358	2492	
AVERAGE		53.8	53.8	46.6	45.3	37.7	39.8		46.1

Table 5b

Size	C	3'	5'	7'	9'	11'	Total	Aver.
			Height					
Small	138	162	116	153	121	126	816	45.3
Medium	171	157	151	132	101	125	837	46.5
Large	175	165	152	123	117	107	839	46.6
TOTAL	484	484	419	408	339	358	2492	
AVERAGE	53.8	53.8	46.6	45.3	37.7	39.8		46.1

ANALYSIS OF VARIANCE

(Tables 5a & b)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares
Height	5	2067.93	413.59 **
Size	2	18.04	9.02
Height x Size	10	856.85	85.69
Error	36	1800	50.00
Total	53	4742.82	

Standard Error of the Difference

$$s_d = \sqrt{\frac{2\,s^2}{n}} = \sqrt{\frac{2 \times 50}{9}} = \sqrt{\frac{100}{9}} = \frac{10}{3} = 3.33$$

Differences to be Significant
(For 36 degrees of freedom)

Least Significant Difference = 3.33 x 2.028 = 6.75 at 5% level *

Least Significant Difference = 3.33 x 2.723 = 9.07 at 1% level **

Table 5c

Comparison for Significance

Size	Control	Height 3'	5'	7'	9'	11'	Difference
Small	46	54					8 *
	46		38.7				7.3 *
	46			51			5
	46				40.3		5.7
	46					42	4
Medium	57	52.3					4.7
	57		50.3				6.7
	57			44			13.00 **
	57				33.7		23.3 **
	57					41.7	15.3 **
Large	58.3	44					3.3
	58.3		50.7				7.6 *
	58.3			41			17.3 **
	58.3				39		19.3 **
	58.3					35.7	22.6 **

Table 5d

Onions Dropped 9 feet-1 at a time versus 4 at a time

Size	Replication	Treatment: 1 at a time	4 at a time	Total	Aver.
Small	1	37	57	94	47
	2	42	54	96	48
	3	42	50	92	46
Total		121	161	282	
Average		40.3	53.7		47
Medium	1	34	49	83	41.5
	2	35	32	67	33.5
	3	32	38	70	35
Total		101	119	220	
Average		33.7	39.7		36.7
Large	1	34	46	80	40
	2	35	45	80	40
	3	48	40	88	44
Total		117	131	248	
Average		39	43.7		41.3
TOTAL		339	411	750	
AVERAGE		37.7	45.7		41.7

Table 5e

Size	Treatment 1 at a time	4 at a time	Total	Aver.
Small	121	161	282	47
Medium	101	119	220	36.7
Large	117	131	248	41.3
Total	339	411	750	
Average	37.7	45.7		41.7

ANALYSIS OF VARIANCE

	Degrees of Freedom	Sum of Squares	Mean Squares
Treatment	1	288	288 **
Size	2	321.3	160.65 *
Treatment x Size	2	65.4	32.7
Error	12	337.3	28.11
Total	17	1012	

Table 5f

Comparison of Treatments

Control-1 at a time-4 at a time. (9 feet)

Size	Replication	Control	Treatment: 1 at a time	Treatment: 4 at a time	Total	Aver.
Small	1	42	37	57	136	45.3
	2	48	42	54	144	48
	3	48	42	50	140	46.7
Total		138	121	161	420	
Average		46	40.3	53.7		46.7
Medium	1	57	34	49	140	46.7
	2	57	35	32	124	41.3
	3	57	32	38	127	42.3
Total		171	101	119	391	
Average		57	33.7	39.7		43.4
Large	1	55	34	46	135	45
	2	62	35	45	142	47.3
	3	58	48	40	146	48.7
Total		175	117	131	423	
Average		58.3	39	43.7		47
TOTAL		484	339	411	1234	
AVERAGE		53.8	37.7	45.7		45.7

Table 5g

Treatment

Size	Control	1 at a time	4 at a time	Total	Aver.
Small	138	121	161	420	46.7
Medium	171	101	119	391	43.4
Large	175	117	131	423	47
Total	484	339	411	1234	
Average	53.8	37.7	45.7		45.7

ANALYSIS OF VARIANCE

	Degrees of Freedom	Sum of Squares	Mean Squares
Treatment	2	1168.07	584.0 **
Size	2	69.41	34.7
Treatment x Size	4	592.15	148.0 **
Error	18	386	21.4
Total	26	2215.63	