D-9

# PROCEEDINGS AND REPORTS

## 1974

# CONDITIONED STORAGE OF SEED

MONDAY AM SESSION CHAIRMAN REX WILSON–Dr. G. Burns Welch and Dr. James C. Delouch of the Seed Technology Laboratory at Mississippi State University have prepared for us the following technical paper–"CONDITIONED STORAGE OF SEED".

Dr. Welch will make the presentation.

**Dr. G. Burns Welch**

**Dr. James C. Delouche**

An increasing number of seedsmen are seriously looking into the feasibility of adding conditioned storage units to their facilities. This current interest in improvement of storage operations can probably be attributed to several factors: (1) a higher overall price structure for seed with more favorable profit margins; (2) increased emphasis on seed quality, especially seed vigor; (3) production "short falls" in recent years which have greatly enhanced the value of carry-over seed stocks; and (4) relatively unpredictable shifts in crops and varieties among farmers resulting from changing commodity prices and/or unfavorable climatic conditions during the planting season. These factors–and others–operate and interact to create a rapidly shifting pattern of both marketing opportunities and problems. Conditioned seed storage is one means which might permit a seedsman to take full advantage of opportunities, while, at the same time, minimizing problems and losses.

Table 1. Moisture contents of field crop seed at equilibrium with various levels of relative humidity. (Approximately 77° F). Source: Seed Technology Laboratory.

| | Relative Humidity (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| Kind | 15 | 30 | 45 | 60 | 75 | 90 | 100 |
| Alfalfa | --- | 6.4 | 7.4 | 8.6 | 13.0 | 18.0 | --- |
| Barley | 6.0 | 8.4 | 10.0 | 12.1 | 14.4 | 19.5 | 26.8 |
| Bermudagrass, Hulled | --- | 8.1 | 9.2 | 10.8 | 13.6 | 17.2 | --- |
| Buckwheat | 6.7 | 9.1 | 10.8 | 12.7 | 15.0 | 19.1 | 24.5 |
| Clover, Crimson | --- | 7.0 | 8.6 | --- | 13.5 | 19.6 | --- |
| Clover, Red | --- | 7.2 | 8.2 | 9.2 | 13.2 | 18.4 | --- |
| Corn, Field | 6.4 | 8.4 | 10.5 | 12.9 | 14.8 | 19.1 | 23.8 |
| Corn, Pop | 6.8 | 8.5 | 9.8 | 12.2 | 13.6 | 18.3 | 23.0 |
| Fescue, Tall | --- | 8.4 | 9.8 | 11.2 | 13.3 | 17.1 | --- |
| Flax | 4.4 | 5.6 | 6.3 | 7.9 | 10.0 | 15.2 | 21.4 |
| Lespedeza, Korean | --- | 7.2 | 8.2 | 9.8 | 13.5 | 18.6 | --- |
| Millet, Pearl | --- | 8.5 | 9.8 | 12.0 | 13.7 | 17.0 | --- |
| Peanut | 2.6 | 4.2 | 5.6 | 7.2 | 9.8 | 13.0 | --- |
| Rice, Milled | 6.8 | 9.0 | 10.7 | 12.6 | 14.4 | 18.1 | 23.6 |
| Rye | 7.0 | 8.7 | 10.5 | 12.2 | 14.8 | 20.6 | 26.7 |
| Ryegrass | --- | 7.5 | 10.0 | 11.2 | 13.8 | 17.0 | --- |
| Sorghum | 6.4 | 8.6 | 10.5 | 12.0 | 15.2 | 18.8 | 21.9 |
| Soybeans | 4.3 | 6.5 | 7.4 | 9.3 | 13.1 | 18.8 | --- |
| Sudangrass | --- | 8.6 | 10.1 | 11.6 | 13.2 | 18.8 | --- |
| Sunflower | --- | 5.1 | 6.5 | 8.0 | 10.0 | 15.0 | --- |
| Timothy | --- | --- | 9.5 | 11.4 | 13.6 | 17.2 | --- |
| Vetch, Hairy | --- | --- | --- | --- | 13.0 | 19.0 | --- |
| Wheat | | | | | | | |
| Soft Red | 6.3 | 8.6 | 10.6 | 11.9 | 14.6 | 19.7 | 25.6 |
| Hard Red | 6.4 | 8.5 | 10.5 | 12.5 | 14.6 | 19.7 | 25.0 |
| White | --- | 8.6 | 9.9 | 11.6 | 15.0 | 19.7 | 26.3 |

Table 2. Moisture content of vegetable seeds at equilibrium with levels of relative humidity. (Approximately 77° F). Source: Seed Technology Laboratory (9).

| | Relative Humidity (%) | | | | | |
|---|---|---|---|---|---|---|
| Kind | 10 | 20 | 30 | 45 | 60 | 75 |
| Beans | | | | | | |
| Broad | 4.2 | 5.8 | 7.2 | 9.3 | 11.1 | 14.5 |
| Lima | 4.6 | 6.6 | 7.7 | 9.2 | 11.0 | 13.8 |
| Snap | 3.0 | 4.8 | 6.8 | 9.4 | 12.0 | 15.0 |
| Beet, Garden | 2.1 | 4.0 | 5.8 | 7.6 | 9.4 | 11.2 |
| Cabbage | 3.2 | 4.6 | 5.4 | 6.4 | 7.6 | 9.6 |
| Cabbage, Chinese | 2.4 | 3.4 | 4.6 | 6.3 | 7.8 | 9.4 |
| Carrot | 4.5 | 5.9 | 6.8 | 7.9 | 9.2 | 11.6 |
| Celery | 5.8 | 7.0 | 7.8 | 9.0 | 10.4 | 12.4 |
| Corn, Sweet | 3.8 | 5.8 | 7.0 | 9.0 | 10.6 | 12.8 |
| Cucumber | 2.6 | 4.3 | 5.6 | 7.1 | 8.4 | 10.1 |
| Lettuce | 2.8 | 4.2 | 5.1 | 5.9 | 7.1 | 9.6 |
| Mustard, Leaf | 1.8 | 3.2 | 4.6 | 6.3 | 7.8 | 9.4 |
| Okra | 3.8 | 7.2 | 8.3 | 10.0 | 11.2 | 13.1 |
| Onion | 4.6 | 6.8 | 8.0 | 9.5 | 11.2 | 13.4 |
| Parsnip | 5.0 | 6.1 | 7.0 | 8.2 | 9.5 | 11.2 |
| Pea | 5.4 | 7.3 | 8.6 | 10.1 | 11.9 | 15.0 |
| Pepper | 2.8 | 4.5 | 6.0 | 7.8 | 9.2 | 11.0 |
| Radish | 2.6 | 3.8 | 5.1 | 6.8 | 8.3 | 10.2 |
| Spinach | 4.6 | 6.5 | 7.8 | 9.5 | 11.1 | 13.2 |
| Squash, Winter | 3.0 | 4.3 | 5.6 | 7.4 | 9.0 | 10.8 |
| Tomato | 3.2 | 5.0 | 6.3 | 7.8 | 9.2 | 11.1 |
| Turnip | 2.6 | 4.0 | 5.1 | 6.3 | 7.4 | 9.0 |
| Watermelon | 3.0 | 4.8 | 6.1 | 7.6 | 8.8 | 10.4 |

## Purpose of Conditioned Storage

A conditioned or controlled seed storage unit is one within which the temperature and/or relative humidity are maintained at specific levels. The "unit" can be as small and uncomplicated as a tin can, or as large and complex as a refrigerated, dehumidified warehouse. Regardless of type or size, however, the basic purpose of conditioned storage is the same: **to increase the longevity of seed**; or in more practical terms, **to maintain the germination and vigor of seed for some specific period**.

It has long been established that seed moisture content and temperature are the most important factors which influence germination and vigor of the different seed kinds during the storage period. It is also well known that there is a direct relationship between seed moisture content and ambient relative humidity. Seed are hygroscopic and absorb moisture from the atmosphere or lose moisture to it until an equilibrium is established between the moisture content of the seed and the relative humidity of the atmosphere (Tables 1 and 2). Because of the relationship between seed moisture content and ambient relative humidity, control of relative humidity within a storage unit is essentially the same as control of seed moisture content.

Although the importance of seed moisture content and temperature in maintenance of seed germination and vigor is recognized in a general way within the seed industry, there is insufficient appreciation and understanding of just **how critical** these factors are in the storage of seed. Many seedsmen just do not believe there is much difference in storage of seed at, say, 13 and 14% moisture, or 70° or 80°F.

Jim Harrington (University of California, Davis) advanced several "rules of thumb" for seed storage about 15 years ago which couch the relationships among seed moisture content, temperature and the storage life of seed in very dramatic terms. These off-quoted "rules" state: (1) the storage life of seed is **doubled** for each 1% decrease in moisture content; and (2) the storage life of seed is doubled for each 10°F decrease in temperature. Since these rules were formulated many workers have shown that they hold reasonably well for most kinds of seed within the ranges of temperature and relative humidity (moisture content) normally encountered in seed storage operation. When Harrington's rules are considered and understood, the seedsman should be able to "see" the difference in storage of seed at 13 or 14% moisture, or 70° or 80°F. At the higher moisture content or temperature–other factors constant–seed will maintain germination and vigor only half as long as they will at the lower levels.

A few other examples might also be useful in dramatizing the critical roles of seed moisture content and temperature in the storage of seed. Several years ago we stored seed of Clark 63 soybeans at 9.0 and 11.2% moisture in sealed plastic bags in an unconditioned warehouse at Windfall, Indiana. Germination of the 11.2% moisture seed began to rapidly decrease after 16 months and was only 10% at 40 months. The 9.0% moisture seed, however, still germinated above 90% when the study was terminated after 40 months. In 1958 we hand harvested seed of the Lee variety of soybean for some mechanical damage studies. Germination of the seed after hand threshing was 98%. Since all the seed were not immediately used for the mechanical damage studies, the remainder was stored at 45°F and 50% relative humidity in one of our cold rooms for possible later use, and then forgotten. During cleaning of the cold rooms this past summer (1974), the Lee soybean seed "turned-up" and a germination test was made to see how they fared during the 16 years storage. Although vigor had obviously decreased substantially, the seed still germinated 90%! Soybean seed were purposely used in these examples because they are classified as a poor storer.

On the basis of voluminous research data and a host of practical experiences, it is easy to demonstrate the technical feasibility of maintaining seed germination and vigor by means of conditioned storage units. Indeed, this aspect can be considered as fact. The difficulties arise in connection with the determination of whether or not conditioned storage of seed is economically practical and feasible. This determination must be made by the management of individual seed operations on the basis of a careful analysis of the many technical and economic factors involved.

## Economic and Operational Factors

The decision to invest in conditioned seed storage facilities should be based on a careful analysis and consideration of several factors.

**Kinds of seed to be stored, their value and extent of storage losses.**

Even at the relatively high current price levels for seed, the even higher (and rising) costs of construction and power require a lot of accurate figuring of costs and benefits to determine the economic feasibility of an investment in conditioned storage facilities for seed. Items that need to be closely figured are: the prevailing prices of the kinds of seed handled and their stability; the differential between seed prices and the grain or other commodity value of the seed; the weight per volume of the different seed kinds since costs of construction, conditioning and storage capacity will reflect storage volume rather than weight of seed stored; the kinds of seed routinely treated with chemicals which precludes any alternative market for them; the normal or projected inventory (volume) of seed; average volume of seed carried over by kind; and the extent of losses resulting from having to dispose of seed in alternative markets, e. g., as grain, or dumping in case of treated seed. Consideration and analysis of the items mentioned and other related ones should permit determination of the benefits that would accrue from conditioned storage facilities.

Those kinds of seed for which the ratio of seed/grain (or alternative market) price is high, yield the greatest benefits from conditioned storage. These include seed of hybrids, flowers, vegetable crops, trees, forage legumes (alfalfa, clovers, etc.) lawn and turf species and varieties, and "speciality" crops (tobacco, peanuts, etc.). Also included are "genetic" seed stocks, foundation seed of some kinds and varieties, and some registered class seed depending on kind, variety and price. We do not imply that other kinds of seed such as wheat, soybean and cotton seed should not be considered for conditioned storage, but only that the "figuring" will have to be much closer to justify the costs involved. For example, conditioned storage might be profitable for reserve or projected carryover stocks of soybeans, wheat, etc., but not for total inventory.

All kinds of seed will be benefited by storage conditioned to the proper level. Benefits from an operation or facility, however, add up to profits only when they exceed the total costs of achieving them. Therefore, factors that will influence the costs of conditioned storage facilities must be given attention.

**Length of the storage period.**

A storeroom can be conditioned to maintain seed germination and vigor for 10-15 years or even longer, but construction and operational costs will be very high. Seed storage of this quality, however, is needed only in a few situations, e. g., storage of breeding lines, genetic banks, etc. Since construction, equipping, maintenance and operational costs are related to the level to which the storage environment is conditioned, hence, the period of storage, a decision on the length of storage must be made early in planning.

In most seed operation, conditioning of storage sufficient to maintain germination and vigor for 18-20 months is sufficient. This will provide good storage for seed from harvest to planting and then until the second planting season after harvest for carry-over or reserve seed stocks. Expensive and valuable seed such as some foundation seed stocks, vegetable and flower seed, etc. may require a storage period of 4-5 years or longer.

**Prevailing climatic condition in area where seed are to be stored.**

The mechanical equipment and power required to condition a seed storeroom to a specified level is related to the reduction in temperature and humidity necessary to meet specified conditions. The cost of operating a conditioned storage facility, therefore, will be less in Minneapolis than in Houston. Normally the air conditioning engineer will analyze the prevailing climatic condition and design accordingly.

**Quality of seed stored.**

There is the rather persistent belief that the "pay-off" from conditioned storage is greater when seed quality is low than when it is high. The economics of this aspect have not been examined critically, but it is our opinion that in the long term, storage of high quality seed in conditioned facilities will yeild greater benefits (profits) than storage of fair to low quality seed. Low quality seed do not store well under any conditions. Conditioned storage facilities will not–in the long run–compensate for poor management of seed operations that result in low quality seed. Therefore, it is most important that seedsmen contemplating installation of conditioned storage units also review–and improve as necessary–all other quality control procedures.

**Quantity of seed to be stored.**

We have already suggested that all seed handled do not have to be stored in conditioned facilities at all time to reap substantial financial benefits. The capacity of conditioned storage needed can be based on the total volume of expensive seeds, the projected or programed volume of reserve or carry-over of less expensive seed kinds, or a combination of these. For example, a conditioned storage unit might have sufficient capacity for all hybrid seed handled plus enough for a 15-20% expected carry-over of soybeans, wheat, etc. The quantity of seed to be stored in conditioned storage, thus, the capacity of storage needed, will be largely determined from considerations mentioned above.

**Loss in seed weight under low humidity storage.**

Several seedsmen who installed conditioned storage units were unpleasantly surprised by the loss in weight of seed during storage, sometimes to the extent that repackaging was necessary to meet weight specs. When the average relative humidity in the conditioned storeroom is less than the average relative humidity under "open" or normal warehouse conditions (as it should be), there is no escaping a loss in weight of the seed stored. For example, if hybrid sorghum seed at 13% moisture are placed in a storeroom conditioned to 40% relative humidity, moisture content will gradually decrease to about 10%. This means that the net weight of every 50 lbs. (original weight) of seed stored will decrease by approximately 1.66 lbs. or 333 lbs. for every 10,000 lbs. stored. The loss in weight, of course, results from a loss of water and not dry matter. Nevertheless, the water lost could have been sold at seed prices.

Once the feasibility of conditioned seed storage facilities is determined and benefits calculated, **the next step is to obtain the services of an air conditioning engineer to estimate the facility and operational costs.** The following section examines the information that needs to be provided to an air conditioning engineer, and the several alternative systems for conditioning seed store rooms.

## Technical Factors

The storage environment of seed can be conditioned by several methods and/or systems. From an engineering point of view the selection of a particular system will largely depend on the conditions specified, **i. e.**, temperature and humidity levels, the type of construction of the storeroom, and the ambient conditions.

The simplest method for conditioning the storage environment of seed is to dry them to a moisture content in equilibrium with a relatively low relative humidity and then package them in a moisture vapor proof container such as a sealed metal can, glass jar, plastic bag, etc. Moisture vapor proof packaging of seed is a very old method for conditioning one component of the storage environment, **viz.**, relative humidity/moisture content. Presently, this system is widely used for vegetable and flower seed. Some of the "bags" used to package field crop seed are also moisture vapor retardant.

The major limitations on use of moisture vapor proof packages for storage of seed are cost,' inconvenience in packaging and handling, and the requirement that the seed have to be dried to a relatively low level (9-10% for most field crop seed) to achieve the desired benefits. The latter requirement is due to the fact that moisture vapor proof packaging controls only relative humidity/moisture content. The packaged seed, of course, could be packaged at higher moisture contents (11-13%) and stored in a cold room, but that would be rather costly.

For field crop seed which are handled in rather large volumes, the room in which they are to be stored is conditioned. Conditioning of a storeroom for temperature and relative humidity requires removal of heat and moisture. These tasks can be accomplished efficiently only in rooms which are specially constructed to retard moisture and heat transfer between the exterior environments and the interior of the storage room. Thus, one of the first considerations in designing conditioned storage facilities is the type of construction and, thus, the quantity of heat and moisture (heat and moisture loads) that will have to be removed to maintain the design conditions.

**Moisture Load.**

In order to maintain relative humidity in a storeroom at a level lower than outside, moisture must be continuously removed from the atmosphere at a rate equal to the rate of infiltration of excess moisture into the room, plus the rate of release of moisture from the seed stored in the room as they come into equilibrium with the lower relative humidity. This moisture load must be calculated by the air conditioning engineer in order to determine the capacity of the dehumidification system needed to maintain design conditions.

Maintenance of a relatively low humidity in a storeroom is greatly enhanced by "tight" construction of the room with suitable materials and incorporation of a moisture vapor barrier in the floor, walls and ceiling. Plastic film of at least 10 mil thickness, and aluminum foil paper-plastic laminated sheeting are excellent vapor barriers. For rooms that are going to be conditioned only moderately, painting of concrete blocks with several coats of a good quality moisture retardant paint, or thorough sealing of the joints of metal panels is generally satisfactory. The room should have a minimum number of doors, and these should be carefully fitted and gasketed to minimize moisture infiltration. There is no need for windows in a conditioned storeroom.

Regardless of how carefully construction is made and which moisture vapor barrier materials are used, moisture will infiltrate into the room, and the rate at which it will do so has to be calculated or estimated by the air conditioning engineer. Calculations of moisture loads due to infiltration are complicated and involve many subjective judgments on rate of moisture transfer through the walls, floor, ceiling, the number of doors, frequency of door opening, how long they remain open, and so on. Because of these uncertainties, moisture loads due to infiltration are usually calculated on the high side.

As mentioned previously, the rate of moisture release from the seed stored in the room as they come into equilibrium with the lower relative humidity is the other important component of the total moisture load. **A dehumidified storeroom is a very inefficient dryer**, but as pointed out previously, seed moisture content will usually decrease by 1-3%. This decrease in moisture content, hence, release of moisture into the room, will not take place during the first day of storage or even the first week. Rather, it will probably occur over a 60 to 90 day period.

Previously, in illustrating seed moisture loss during conditionedjstoreage, we used the example of hybrid sorghum seed decreasing in moisture from 13% to 10% and calculated that 1.66 lbs. of water would be lost from every 50 lbs. (original weight) of seed. Thus, in a conditioned storeroom with a capacity of 20,000 fifty-pound bags, 33,220 pounds (or pints) of water will be released in the conditioned storeroom during a 60 to 90 day period. Thus, the equipment used to maintain the desired humidity must be able to also take care of the moisture lost from the seed. We should point out, however, that the example used is rather extreme. Generally, the seed will be sufficiently dry before they are placed in the storeroom so that no more than 1-2% moisture will be lost.

**Heat load.**

Maintenance of a storeroom temperature lower than the ambient condition requires sufficient air cooling capacity to reduce the temperature of the air and materials in the room (seed) to the design condition, and to maintain it at that level against heat transfer through the walls, floor, and ceiling, as well as against the heat released in the room from dehumidification processes, motors, lights, and seed. Heat load estimates are always important, but they are doubly so in the design of dehumidified storerooms. Dehumidification (removal of moisture vapor from the atmosphere) is a heat-releasing process and the temperature in a dehumidified storeroom will rise unless the heat released is compensated for by air cooling.

Air conditioning engineers seldom have much trouble calculating heat loads. The heat load will depend on the construction materials, the type and thickness of insulation, the quantity of seed in the storeroom, its temperature at the time it is placed in storage, wattage of lights, motors, and the pounds of moisture removed per hour by the dehumidification system.

Design of a conditioned storeroom involves specifications of construction materials and features such as moisture vapor barriers and insulation which will reduce heat and moisture loads to economically minimal levels. This is especially important in these times of soaring power costs. Economic minimization of moisture and heat loads will, in turn, greatly influence the types of air cooling and dehumidification systems needed to achieve and maintain the design conditions of temperature and relative humidity.

Conditioning System

Conditioning of the environment in a seed storage room requires air cooling, dehumidification, or both. The type and amount of air cooling and/or dehumidification is determined by the kind of seed, type of construction, length of the storage period, and ambient conditions. There are three general systems for conditioning a seed storeroom and each has its advantages and limitations. These are: (1) "air conditioning"; (2) refrigeration with integral dehumidification; and (3) refrigeration coupled with desiccant dehumidification.

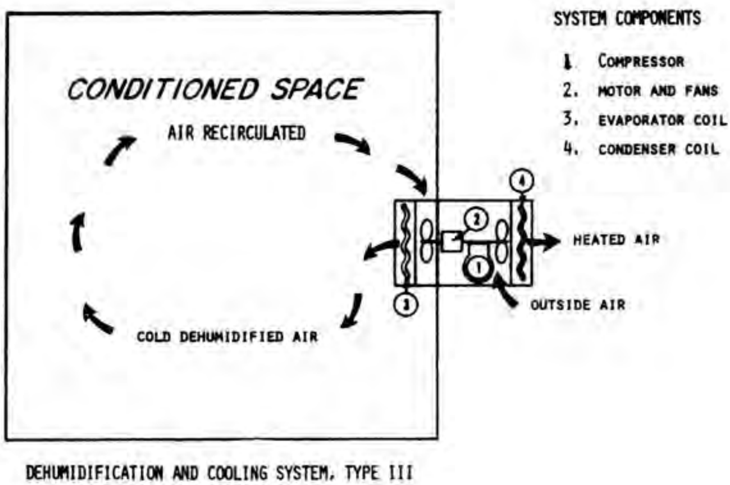



Figure 1. Schematic diagram of an "air conditioning" system for a seed store room.

**Air Conditioning** (Figure 1.)

In our view the common air conditioning system as used in office buildings and houses has been overlooked as a means of conditioning seed storage rooms. Properly engineered systems of this type can maintain a temperature of 65°F and 55-60% relative humidity which is adequate for 12 to 20 months storage of most kinds of field crop seed provided the seed are of good quality. The air conditioning engineer should select and specify components and a design for the system which have a "higher than normal" dehumidification capacity in order to achieve 55-60% r. h. and prevent "freeze-ups." The heat capacity of the seed stored in the room should also be taken into consideration.

Although most buildings regardless of construction can be air conditioned, economic efficiency requires that they be reasonably tighter constructed, insulated at least in the ceiling if of concrete, brick or concrete block, and insulated both ceiling and walls in the case of pre-engineered metal construction.

In the warm-humid areas of the South, it is probably best to "air condition" continuously. However, in the Mid-West and other areas with cold winters, the air conditioning system can be "turned off" in the Fall when average ambient temperatures begin to drop below 50°C and then turned on again in the Spring when average ambient temperature rises above 55-60°F.

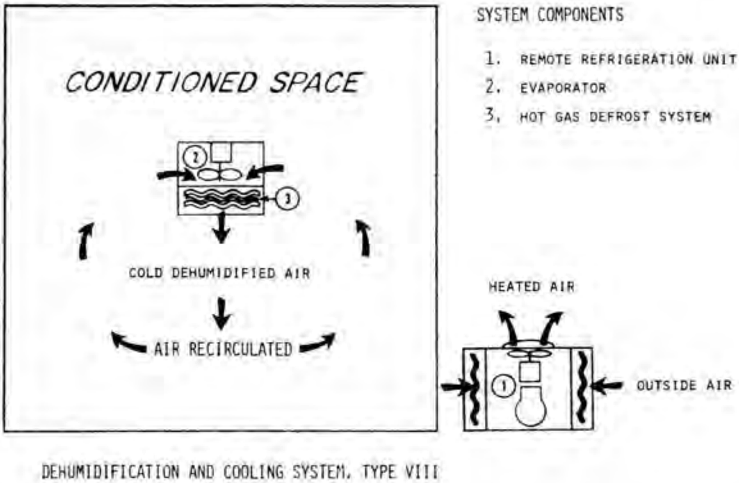



Figure 2. Schematic diagram of refrigeration system with intergral dehumidification for conditioning seed storage units.

**Refrigeration with Integral Dehumidification** (Figure 2.)

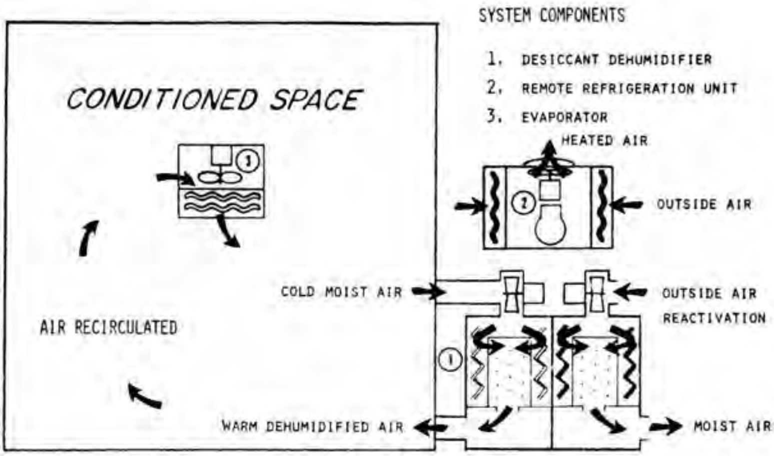
Refrigeration systems are widely used for cold storage of many products: meat, furs, vegetables and fruit, potatoes, etc. In most cases conditions in a cold room are "cold and wet" as they need to be for the products cited. Because the usual environment in a cold room is "cold and wet" many refrigeration engineers have little experience–if any–in designing a refrigeration system which will maintain "cold and dry" (low humidity) conditions.

There is usually little difficulty in developing specifications for a cold room conditioned for temperatures down to freezing or even below freezing, e. g. heat loads, construction and insulation requirements and heat removal capacity. The problem usually arises in designing for humidities lower than 60-70%.

A refrigeration system can maintain a temperature of 40°F and a relative humidity of 40-45% when properly engineered.

Dehumidification by a refrigeration system is accomplished when the temperature of the air drawn across the refrigerated coils for cooling is reduced below the dew point. Moisture is condensed on the coils, collected in a drip pan, and drained form the room through a plastic or metal pipe in a manner similar to the outside "drip" from a window type air-conditioner. In highly conditioned rooms, e. g., 55°F or less, the dew point of the air may be below freezing; thus, moisture is condensed on the coils as frost on ice. The frost or ice will accumulate insulating the coils and reducing cooling capacity unless it is periodically removed by defrosting. Defrosting is usually accomplished at automatically timed intervals by activation of electric heating strips on the coils or by reversal of the flow of hot discharge gas so that it passes through the coils.

Humidity control must be "built into" the coil design of a refrigeration system. For humidities below 50°F at least a 20° to 25° temperature difference between room temperature and refrigeration suction temperature should be maintained. One of the best methods for achieving low humidities at low temperatures is "reheating". Reheating can be accomplished by a strip heater or heating unit located in the air discharge from the unit cooler and operated by a humidistat. The added heat keeps the refrigerating compressor operating longer, thus, increasing its moisture removal capacity. The reheat method is a single, direct and easily maintained system, and not too expensive to operate if the coil and compressor are properly designed.




DEHUMIDIFICATION AND COOLING SYSTEM, TYPE VII

Figure 3. Schematic diagram of refrigeration system combined with desiccant dehumidifier for conditioning seed storage units.

**Refrigeration with Desiccant Dehumidification** (Figure 3.)

Considering the difficulties in obtaining a properly designed refrigeration system with integral and contractors, a refrigeration system coupled with a desiccant dehumidifier is a good alternative. The refrigeration system reduces the temperature inside the room to the desired level and accomplishes such dehumidification as is within its design capability. The additional dehumidification necessary to achieve the desire level is done by the disiccant dehumidification system.

In desiccant dehumidification, air is drawn through or across a bed of chemical desiccant which absorbs the moisture vapor. The dry air is then blown back into the room. Since desiccants (commonly, silica gel) can absorb only a certain quantity of moisture, they must be periodically dehydrated (reactivated) by heating. This is usually accomplished automatically by periodic activation of heaters in the desiccant bed, or continuous heating in the case of rotating desiccant beds. Desiccant dehumidifiers are more efficient than refrigeration condensation systems at low temperature and can maintain a relative humidity as low as 10%.

The capacity of the dehumidification system must be "matched" to the cooling or refrigeration system, the type of construction, the desired level of relative humidity, and the moisture load. Most manufacturers of desiccant dehumidifiers will determine the desiccant dehumidification capacity required for a seed store room when provided with the necessary data on temperature, construction, volume, quantity of seed stored, etc. so that the moisture load can be calculated.

## Management Consideration

Proper management of a conditioned storage facility for seed is essential for realization of expected benefits. The investment in construction and equipment, and the cost of operating the facility are simply too high for hip-pocket management.

Good management should begin immediately after the decision has been made to establish a conditioned storage unit. **The first management action should be to obtain the services of a qualified, experienced, air conditioning or refrigeration engineer.** Many "air conditioning" or "climate control" companies have staff engineers whose services are available as part of the sales/construction package. The engineer or company selected should have experience with a wide range of air conditioning systems and be able to point to a variety of successful installations.

Other management decisions and actions prior to completion of the facility and actual operation will be related to the type and quality of construction, the type of conditioning system, and accessories. The importance of good construction has already been emphasized. Skimping on vapor barriers and insulation might reduce the capital investment, but it will surely add substantially to operational costs. Likewise under-sizing of the conditioning equipment to reduce costs will usually result in greater costs in the long run. The conditioning systems should be designed to meet specifications under the most unfavorable ambient conditions of temperature and relative humidity.

During the early stages of planning, management should carefully consider the movement of seed into and out of the conditioned storage. An insulated, gasketed "standard" refrigeration door 3 to 4 feet wide will provide for good movement into and out of a small storeroom. For large rooms, however, a door(s) of this type is simply not satisfactory. In cases where seed are to be stored on pallets and moved by fork-lift, electrically operated rolling doors or other similar type, with well-fitted seals and of sufficient width for good clearance are necessary.

The economic benefits (profits) from a conditioned storage facility will be influenced by how efficiently the conditioned space is utilized. For this reason, the dimensions of the storeroom should be established on the basis of an arrangement(s) of seed within the room which will permit efficient load-in and shipping out and also make maximum utilization of space. Nothing could be more disconcerting than to realize during the first loading of a conditioned storeroom that if it were 10% wider, capacity could be increased by 30-40%.

The number of conditoned seed storage units also needs to be considered during the early planning stage. When more than one level of conditioning is required, one unit will obviously be insufficient. Even in the case where only one level of conditioning is needed, subdivision of the storeroom into several smaller, independently controlled units might be advantageous. Although construction and equipment costs are higher for multiple unit conditioned storerooms, the possibility of concentrating seed into one to several small rooms during periods of low inventory, and turn-off of other units not needed will reduce operational costs—an important consideration in these times of escalating costs.

Management should develop a plan for use of the facility prior to the time it becomes operational. This plan should establish the kinds of seed to be stored, a general schedule of load-in and shipping out, stacking arrangements, policies concerning the use of lights and opening doors, maintenance, etc. Maintenance should include a daily inspection of the facility and control equipment.

Since the purpose of conditioned storage is to control temperature and relative humidity at levels which will permit maintenance of seed quality for the period desired, some monitoring system should continuously record both temperature and relative humidity and the records should be kept on file for review as needed.

## SUMMARY

Several points should be emphasized in summarizing this discussion of conditioned storage for seed.

1. Conditioned storage facilities maintain seed quality for periods longer than in open storage through control of temperature, relative humidity or both.
2. Conditioned storage is expensive; therefore, the decision to invest in conditioned storage should be based on an economic analysis of costs and benefits.
3. The level(s) of conditioning selected will be determined by the kinds of seed to be stored and the period of storage.
4. The services of an experienced air-conditioning engineer or company should be obtained early in planning—even during the feasibility study phase.
5. The conditoned storage facility must be properly managed to reap the expected benefits (profits).