SYSTEMS FOR CONTROLLING RELATIVE HUMIDITY AND TEMPERATURE [1]

James M. Beck [2]

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 for 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.

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.

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[2] Mr. Beck was formerly Engineer Technician, Seed Technology Laboratory, MSU; presently, with the UN-FAO, Los Banos, Philippines.

Refrigeration-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 temperature, they lose efficiency below $70^{o}F$ 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 beds of desiccant, a portion of which is 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 alone 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 dehumifidier. At temperatures below $50^{\circ}F$, silica gel will remove nearly 90% of the moisture from the air stream. At $100^{\circ}F$ 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

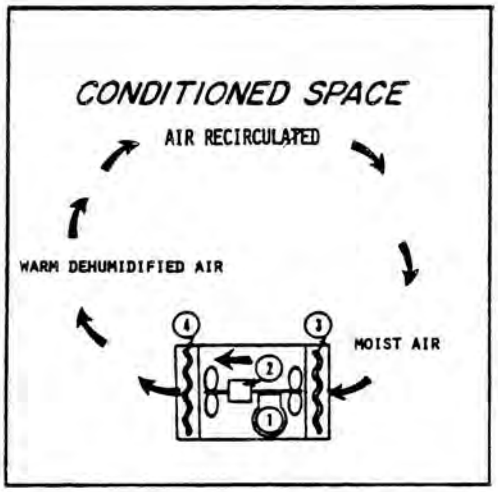
As shown in the first illustration, a refrigeration-type dehumidifier is placed inside the conditioned space. This self-contained unit consists of the following components: refrigeration compressor, motor and fans, evaporator and condenser coils. The air inside the room is recirculated through the unit 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 buildup can be kept to a minimum.

Dehumidification and Cooling System, Type III

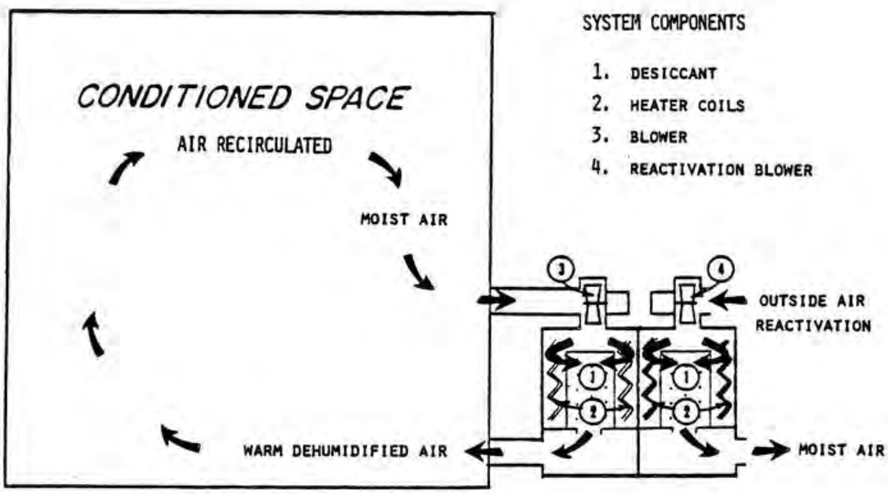
A conventional type air conditioner can be used to maintain temperature and relative humidity when the reduction of temperature is necessary for control of the sensible heat load. As shown in the third illustration, only the evaporator section of the refrigeration unit is placed inside the conditioned 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



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

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 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 can be turned on and off automatically as the humidity inside the conditioned space changes.

Dehumidification and Cooling System, Type IV

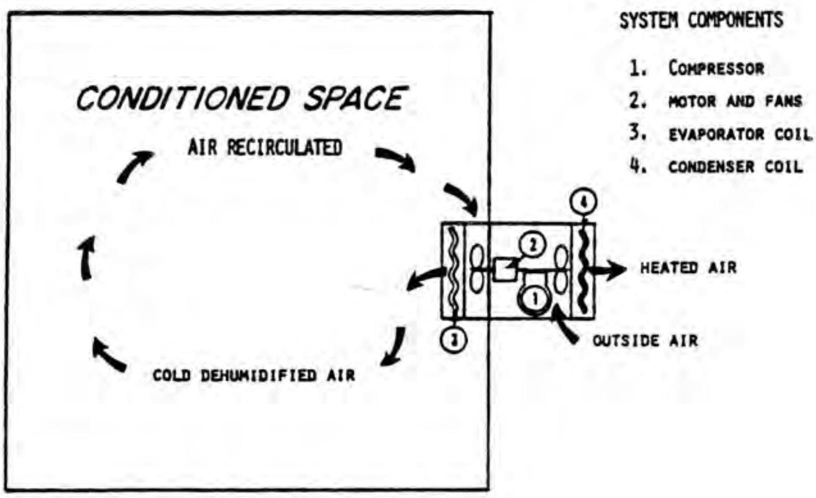
The system shown in the fourth illustration consists of a desiccant dehumidifier with a water after-cooler. The water cooler is used to reduce the air temperature as it leaves the desiccant dehumidifier. The size of the after-cooler coil and the quantity and temperature of the water that passes through 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.

Dehumidification and Cooling System, Type V

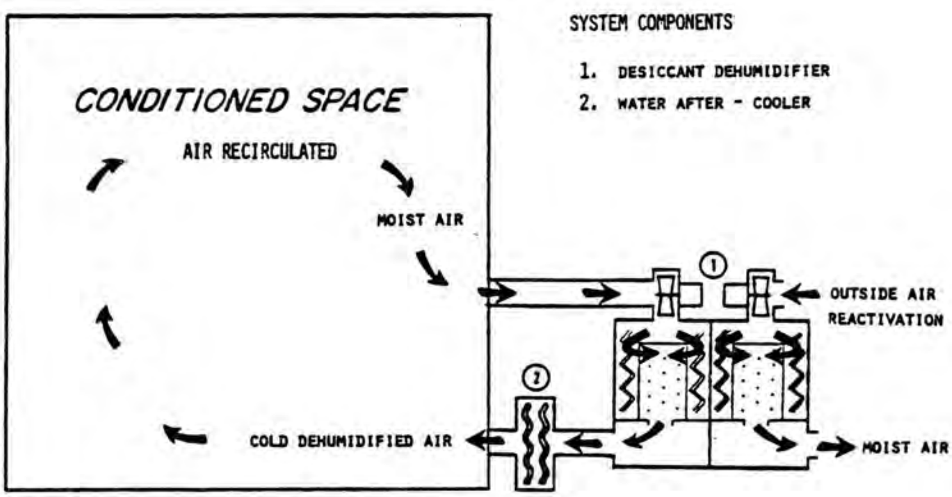
The fifth illustration shows a high moisture removal system that utilizes a refrigeration unit in conjunction with a desiccant dehumidifier. Cooling for a pre-cooling coil and an after-cooling coil is provided by the refrigeration system. Since silica gel can remove nearly 90% of the moisture from air at a temperature below 50°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°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

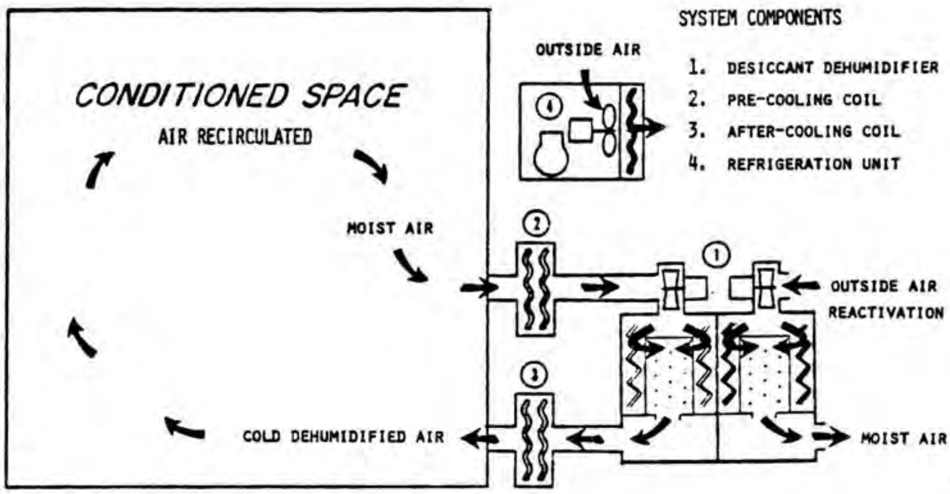
A simple system for controlling the temperature inside a conditioned space while removing large quantities of moisture at higher temperatures is shown in the sixth illustration. A self-contained refrigeration type dehumidifier located inside the conditioned space to remove the moisture from the air is 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°F and relative humidities below 50%.



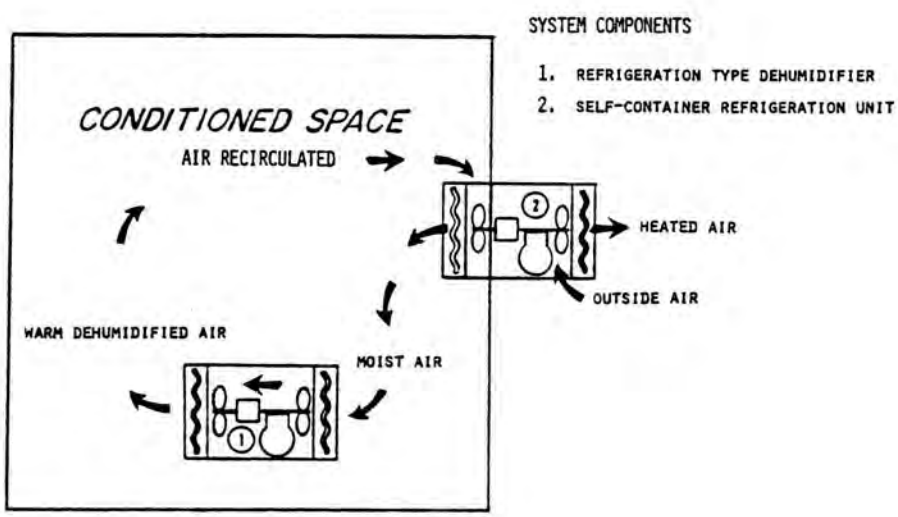
DEHUMIDIFICATION AND COOLING SYSTEM, TYPE III



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE IV



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE V



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE VI

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.

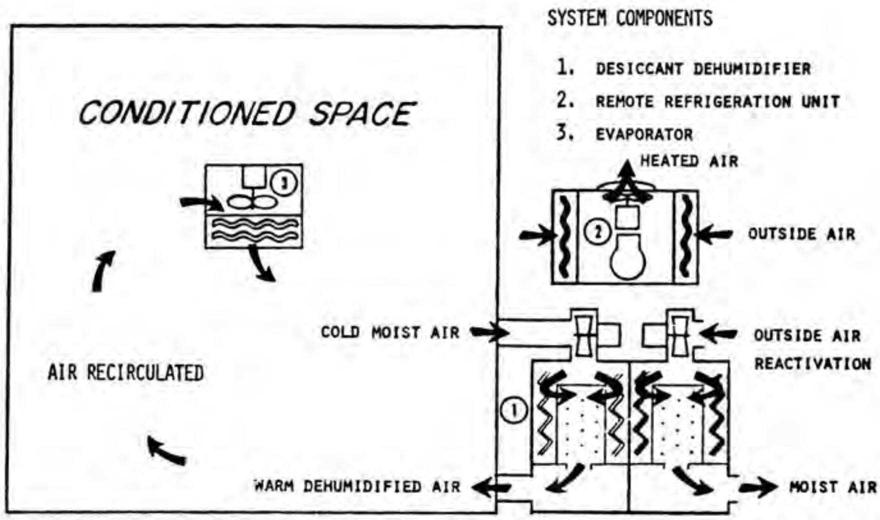
The refrigeration systems will dehumidify (within limits of design) as we'l as cool the air. It works independently of the desiccant unit; however, in normal operation the two systems complement each other. The desiccant dehumidifier has a much higher moisture removal capacity by having cold moist air 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.

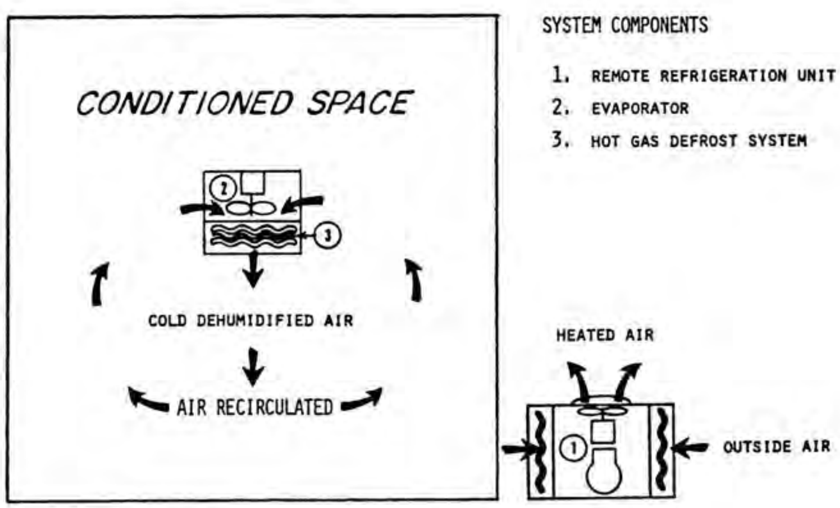
Dehumidification and Cooling System, Type VIII

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.



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE VII



DEHUMIDIFICATION AND COOLING SYSTEM, TYPE VIII