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## SEED STORAGE TO MAINTAIN QUALITY

G. Burns Welch <sup>1/</sup>

After seeds have been produced and up-graded by proper processing, they must be stored in a suitable environment to retain this high quality. The retention of high seed viability and vigor is a problem encountered in many parts of the world. The humid Southern region of the United States is often a troublesome area for storing seeds in open warehouses. In any humid locality, it is necessary to provide an environment that will minimize the metabolic activity of the seed particularly if they are to be stored for longer than one season. The equilibrium moisture content and the temperature of the seeds during storage are the two major factors that influence their longevity. If the moisture content is too high, seed deterioration can be quite rapid. Some of the deteriorative effects due to moisture and a favorable temperature are shown in Table 1.

Table I. Effect of moisture content on seeds during storage.

Moisture Content	Deteriorative effects that can occur during storage
35 to 60%	Germination begins
16%	Heating begins. Due to increased rate of respiration and micro-organism activity
12 to 14%	Mold growth may begin
8%	Insect activity begins

### Equilibrium Moisture Content

When the vapor pressure due to the moisture in seeds is different from the vapor pressure of the atmosphere, there will be an exchange of moisture between the seeds and the atmosphere. If the vapor pressure

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inside the seeds is higher than the vapor pressure of the atmosphere, the seeds will lose moisture to the atmosphere. The opposite effect will occur if the vapor pressure of the atmosphere is greater than the vapor pressure inside the seeds. This exchange of moisture will continue until the seeds reach an equilibrium moisture content, at which time there is no further exchange of moisture.

The equilibrium moisture content of seeds is influenced by the relative humidity and temperature of the atmosphere. The relative humidity has a greater effect. The equilibrium moisture content of several seeds at different relative humidities and at a constant temperature of 77° F. is shown in Table II.

Table II. Equilibrium Moisture Contents at Different Relative Humidities.

Moisture Content: (Wet Basis) In Percent						
Relative Humidity (Percent)	15	30	45	60	75	90
Barley	6.0	8.4	10.	12.1	14.4	19.5
Corn, YD	6.4	8.4	10.5	12.9	14.8	19.1
Rice, rough	5.6	7.9	9.8	11.8	14.0	17.6
Sorghum	6.4	8.6	10.5	12.0	15.2	18.8
Soybeans	-	6.2	7.4	9.7	13.2	-
Wheat, white	6.7	8.6	9.9	11.8	15	19.7

Source: ASAE Yearbook, 1965.

If the temperature is increased 20° F., the seed moisture content will be reduced approximately 2%. Conversely, a 20° F. reduction in temperature will increase seed moisture approximately 2%.

#### Effect of Relative Humidity and Temperature on Seed during Storage

The results of a storage study in which sorghum seed were stored at different relative humidities and temperatures are shown in Table III. These data show that the relative humidity has a more pronounced effect on seed longevity than temperature. The data also indicate that, as the moisture content of the seed increases, the temperature must be decreased for safe storage, and vice versa.

Table III. Germination percentages of sorghum seed after various intervals of storage at different temperatures and relative humidities.

Relative Humidity %	Temperature ° F.	Months of Storage						
		0	2	4	6	8	10	12
20	50	95.2	93.5	94.2	95.7	95.7	94.7	96.5
	68	95.2	94.0	94.2	94.7	95.0	96.5	95.7
	86	95.2	93.2	92.5	95.2	93.0	94.0	94.5
40	50	95.2	94.2	93.7	95.0	95.0	96.2	95.0
	68	95.2	93.0	93.7	92.7	93.7	93.0	94.7
	86	95.2	93.0	93.7	95.5	93.2	95.2	92.0
60	50	95.2	93.2	93.2	95.2	93.5	94.5	97.2
	68	95.2	92.2	94.5	94.7	95.0	93.7	92.2
	86	95.2	92.5	94.2	89.2	89.5	86.2	75.2
80	50	95.2	92.7	92.3	56.7	47.5	44.5	38.0
	68	95.2	56.5	47.2	39.2	10.5	0.0	0.0
	86	95.2	45.0	0.0	0.0	0.0	0.0	0.0
100	50	95.2	85.5	44.0	22.7	0.0	0.0	0.0
	68	95.2	41.0	0.0	0.0	0.0	0.0	0.0
	86	95.2	1.0	0.0	0.0	0.0	0.0	0.0

There are three general rules of thumb that are commonly used in seed storage: (1) for safe storage conditions, the sum of the percent relative humidity plus temperature in degrees Fahrenheit should not exceed 100; (2) for each one percent decrease in moisture content, the storage life is doubled; (3) for each 10° F. decrease in temperature, the storage life is doubled. According to these rules, seeds stored at 8% moisture content will maintain good viability twice as long as seeds stored at 9% moisture content. Seeds stored at 60° F. will maintain good viability twice as long as seeds stored at 70° F. There is also a complementary effect between the two factors; therefore, theoretically, seeds stored at 8% and 60° F. will maintain good viability four times as long as seed stored at 9% moisture and 70° F.

## Control of Relative Humidity and Temperature In a Seed Storage Room

Because the relative humidity is often too high for safe seed storage, it is necessary to provide some means for reducing it to a safe level in a storage room. The relative humidity in a storage room can be controlled by mechanical refrigeration, a desiccant type dehumidifier, or a combination of the two.

Before discussing the principles of dehumidification by mechanical refrigeration, it would be relevant to take a look at how the properties of air will change with an increase or decrease in temperature. Referring to Figure 1, we see that one pound of dry air at 80° F. and standard atmospheric pressure will occupy a volume of 13.6 cubic feet. If this one pound of air is heated to 110° F., its volume will increase to 14.4 cubic feet. If the temperature is decreased, it will occupy 13.1 cubic feet at 60° F. For each 40° F. change in temperature, the volume will change roughly one cubic foot.

When air contains the maximum amount of water vapor possible without any of the water vapor condensing, it is said to be saturated. The amount of vapor contained in one pound of air at saturation is influenced by the temperature of the air. Referring again to Figure 1, you can see that one pound of air at 80° F. would contain .022 pounds of water at saturation. If the air is heated to 110° F. and then saturated, it would contain .059 pounds of water. At 60° F. and 40° F., the water-holding capacity is decreased to .011 and .005 pounds of water vapor, respectively. This shows that as the temperature of air is decreased, its water-holding capacity is also decreased.

Another term used when referring to amount of water vapor in the air is relative humidity. This is the ratio of the amount of moisture actually in the air to the amount the air would contain if it were saturated. For example, suppose the air temperature is 80° F. and the relative humidity is 50%. This means the air contains .011 pounds of water vapor which is one-half the amount it is capable of holding at saturation. What would happen to the relative humidity if this same air is heated to 110° F. or cooled to 60° F. without any change taking place in the amount of water vapor? First, let us calculate the relative humidity at 110° F.

$$\text{R. H.} = \frac{.011}{.059} = 18.7\%$$

At 60° F. the relative humidity would be

$$\text{R.H.} = \frac{.011}{.011} = 100\% \text{ fully saturated}$$

At 40° F., the air would still be fully saturated and .006 pounds of water would be condensed. This condensation occurs because the air at 80° F. and 50% R.H. contains twice the amount of moisture it is capable of holding at 40° F.

These examples show why the relative humidity in a storage room will increase as the temperature is lowered unless some means is provided for removing the moisture from the air.

Dehumidification by mechanical refrigeration operates on the principle that the water vapor in the atmosphere will condense when it comes in contact with a surface at a sufficiently low temperature. This is basically the same reason that moisture will accumulate on the outside of an iced tea glass. The temperature at which condensation occurs is referred to as the dewpoint. To accomplish dehumidification with a refrigeration system, the cooling coils must be a few degrees below the dewpoint for the desired combination of relative humidity and temperature (Figure 2). For example, suppose we wish to maintain an atmospheric condition of 60° F. and 50% R. H. in a storage room. Referring to a psychrometric chart (page ), we find that the dewpoint for this combination of temperature and relative humidity is 40° F. The refrigeration system would be designed to have a coil temperature a few degrees below the dewpoint. Theoretically, any time the relative humidity goes above 50%, moisture will condense on the coils and drain out until the relative humidity is decreased to 50%.

Let us now consider another example in which the desired atmospheric conditions are 40° F. and 50% R.H. Referring again to the psychrometric chart, we find the dewpoint to be 25° F., which is below freezing. The moisture that collects on the coils will freeze and build up a layer of ice on the coils. When the system is operating with a coil temperature below freezing, it is necessary to provide some type of heating system to defrost the coils. The system can be controlled with a time clock to stop periodically the refrigeration compressor and turn on the heat system to defrost the coils.

The design of a refrigeration system for both cooling and dehumidification is a very technical problem. It is of utmost importance that the different components in the system be well balanced. Anyone desiring to use refrigeration dehumidification at temperatures below 65° F. should seek the advice of a competent refrigeration engineer.

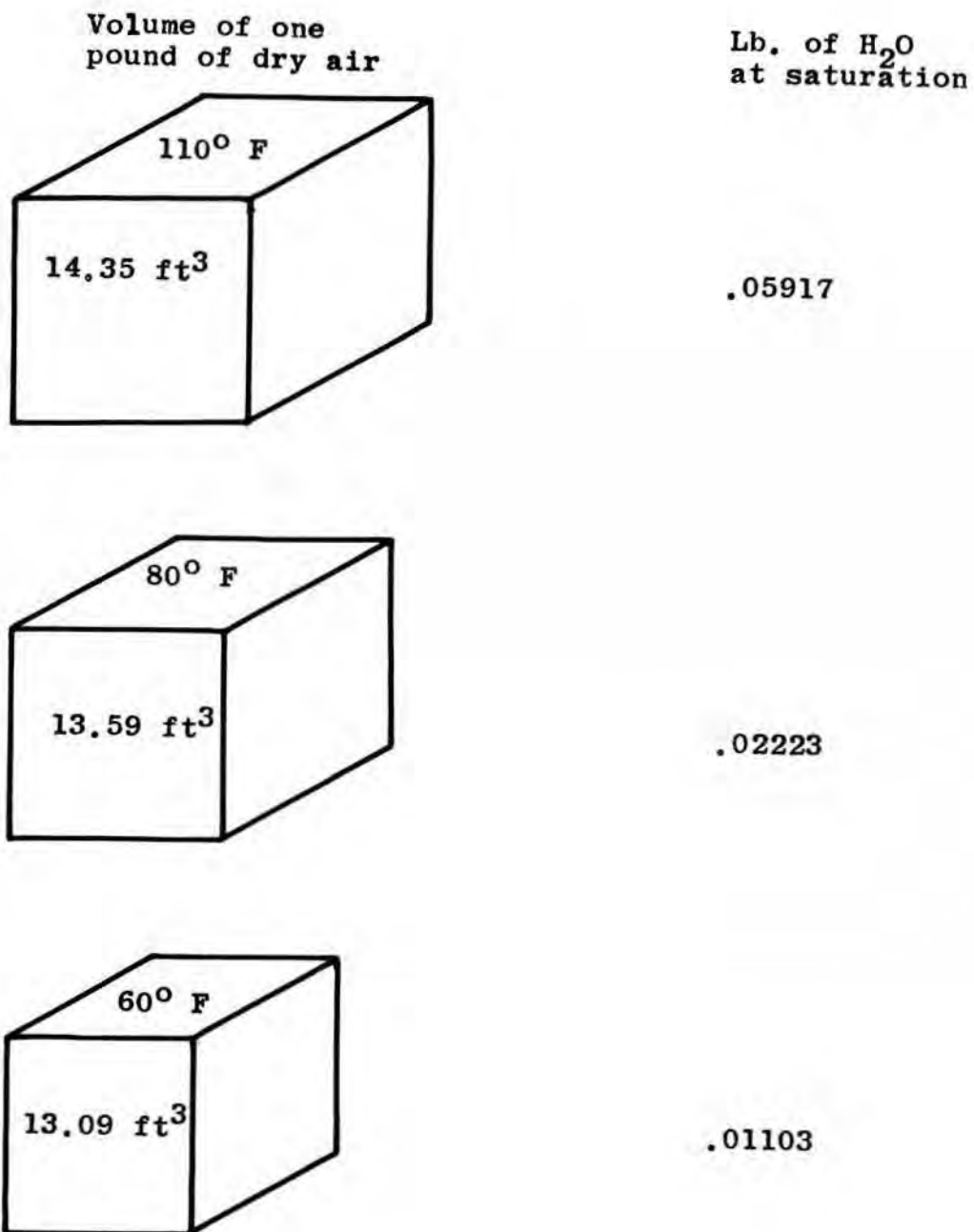


Figure 1. Properties of air. The volume and water holding capacity varies with the temperature.

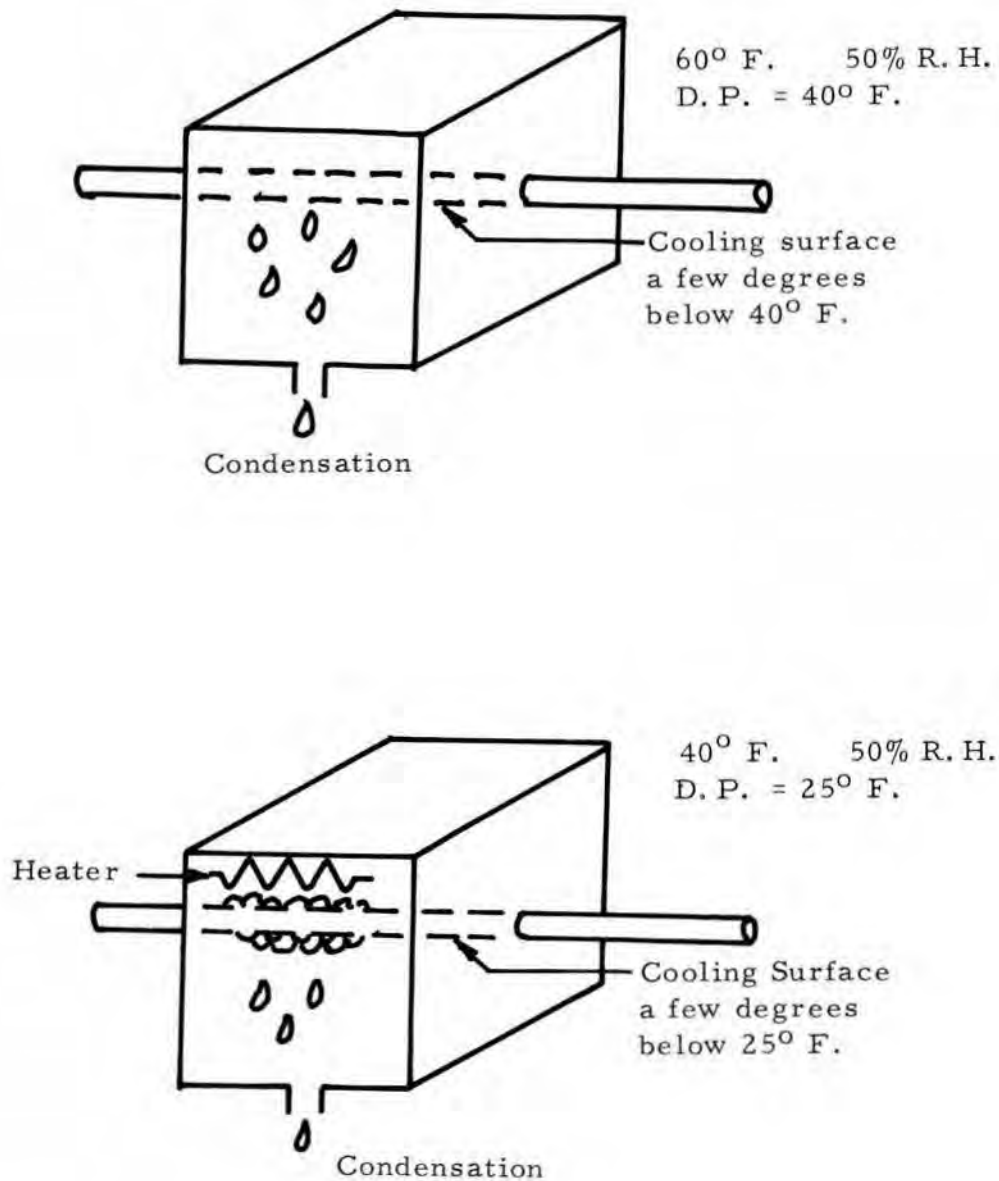


Figure 2. To maintain a particular temperature and relative humidity, the temperature of the cooling coil must be a few degrees below the dewpoint temperature.



Another method for controlling the humidity in a storage room is by the use of a desiccant dehumidifier. This type dehumidifier operates on the principle that the air in the storage area is passed through a bed of dry desiccant such as silica gel. This is a highly porous material capable of absorbing as much as 40% of its own weight in water vapor. The dehumidifiers commonly used on storage applications consist of two beds of desiccant about four inches thick. While one bed is drying air from the storage room, the other bed is being reactivated (Figure 3). This is accomplished by passing outside air, which has been heated, through the moist bed to drive out the moisture. A humidistat can be used to control the dehumidifier to maintain the desired relative humidity. This type dehumidifier can operate over a wide range of temperatures from minus 40° F. to plus 175° F. providing the proper desiccant is selected for the particular application.

A factor not to be overlooked is that a desiccant dehumidifier will add heat to the storage room. In some cases, the temperature of the air being dried increases as much as 30° F. to 40° F. in passing through the drying bed. This is due to the latent heat of adsorption and sensible heat gain from re-activation of the desiccant. If this results in an inside temperature higher than desired, some means of removing the excess heat must be provided. This can be accomplished by air conditioning or by putting a water-cooled heat exchanger in the discharge duct of the dehumidifier.

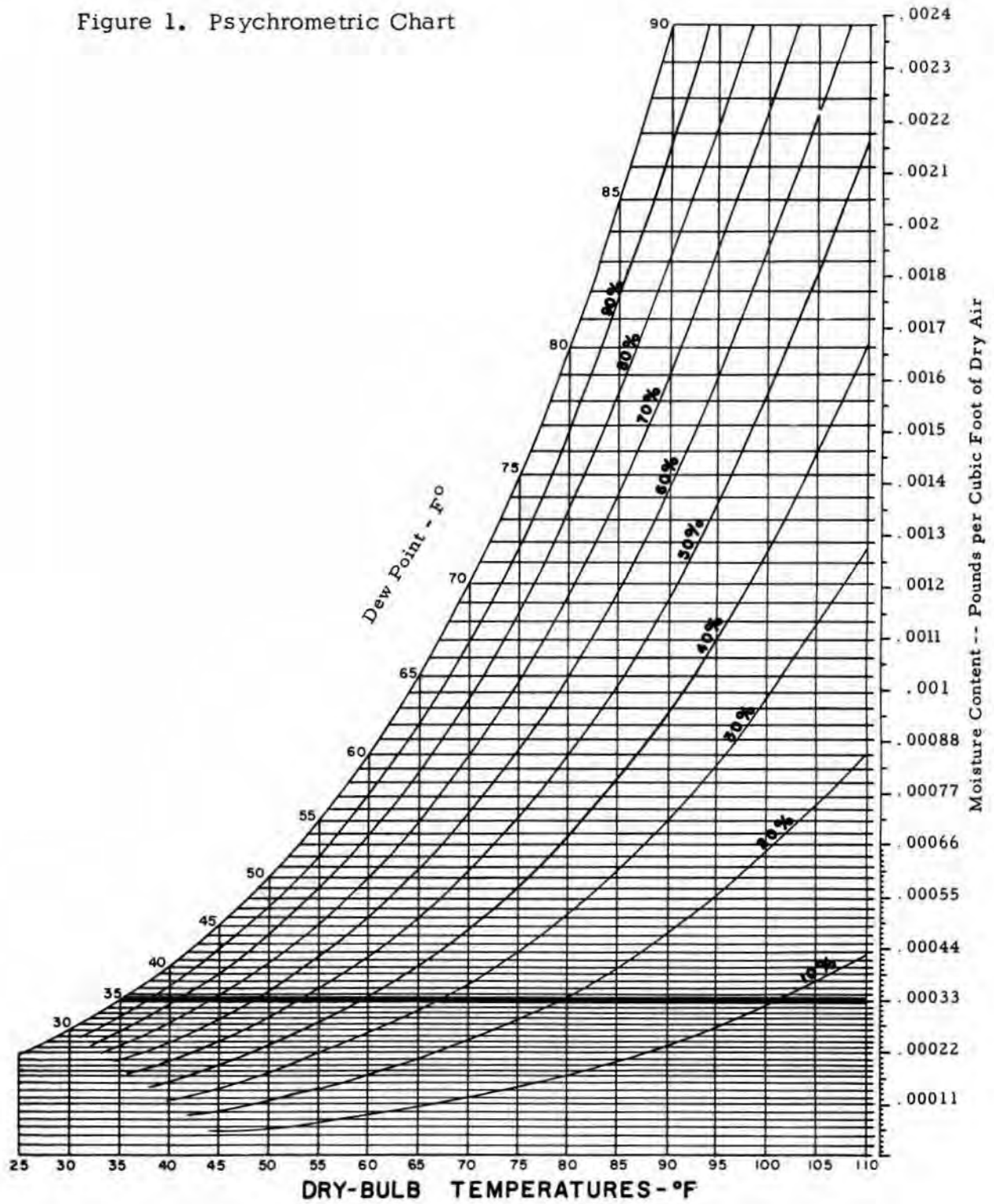
A combination of the two systems previously mentioned can be used quite satisfactorily when the desired relative humidity level is below that which can be maintained by the refrigeration system. The refrigeration system will maintain the desired temperature and will remove some of the moisture from the air. The desiccant dehumidifier then reduces the relative humidity to the desired level.

#### Construction of Storage Room

The type of construction is another item of great importance in a seed storage facility. Before selecting the type of construction to be used, the design conditions must be known. What are the outside atmospheric conditions and what temperature and relative humidity will be maintained inside? Once these are known, the proper thickness of insulation can be selected. A good vapor barrier should be placed on the warm side of the insulation to prevent the movement of water vapor through the wall and into the storage room.

Once the design conditions and type of construction are known, the total heat load can be calculated. This includes the heat transferred through the structure itself, product load, air changes, and heat from

Figure 1. Psychrometric Chart



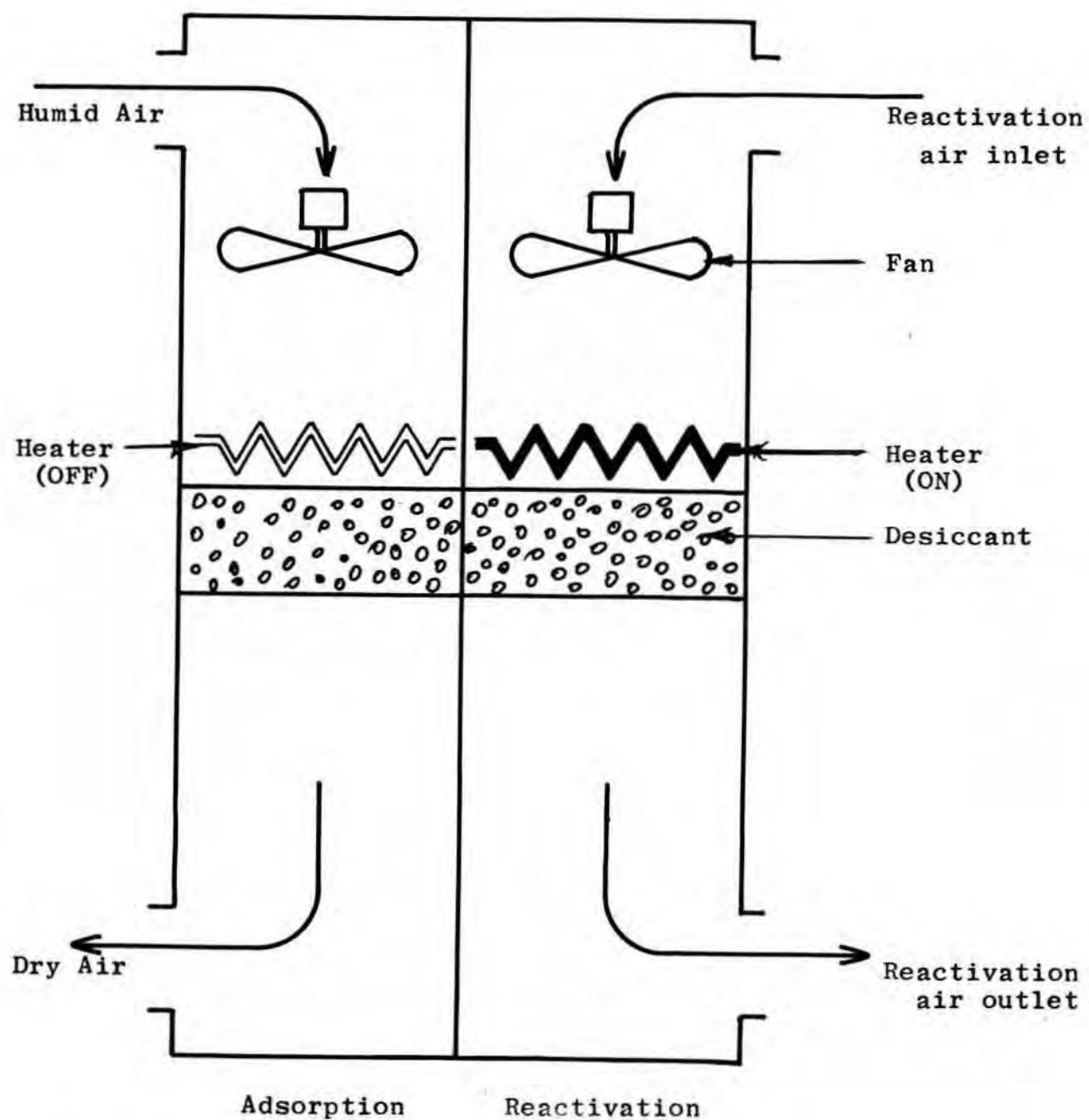


Figure 3. Schematic diagram of an adsorption dehumidifier.

lights, motors, and personnel. When the total heat load is known, the proper size of refrigeration equipment can be selected. Maximum efficiency and economy are attained only when the cooling equipment operates most of the time. This is particularly true when dehumidification is by refrigeration.

A storage room should be constructed to allow easy housecleaning. The doors and pipe opening through the wall should fit tightly to make the room as near vermin- and rodent-proof as possible.

### Control of Insects

The control of insects is another factor in maintaining high quality seeds during storage. At temperatures below 50° F., damage from insects becomes insignificant. Mold growth is also inactive at lower temperatures.

When seeds are stored at temperatures above 50° F., insects can be controlled by treating the seeds with a suitable insecticide. This can be applied at the same time the seeds are treated with a fungicide.

### Summary

Seeds of high quality must be stored in a suitable environment to retain their viability and vigor. A suitable storage environment is obtained when the sum of the percent of relative humidity and the temperature in degrees F. does not exceed 100. The humidity in a storage room can be controlled satisfactorily by mechanical refrigeration, desiccant dehumidifier, or a combination of the two. Relative humidity is more important than temperature in seed storage. The storage facility should be designed for easy housecleaning and also be as near vermin- and rodent-proof as possible.