A CLOSER LOOK AT ENERGY LOSSES IN DRYING LUMBER

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Some of you may recall that last year in Canada, I gave a talk on "The Energy Required to Dry Lumber." You may also recall discussion of the question--How come in theory it takes 1,200 to 1,300 BTUs to evaporate one (1) pound of water but in practice it requires much more?

That talk seemed to have sparked people's interest because I have received several phone calls from people to discuss this subject. Mike and I have given this subject a great deal of thought, and we have some ideas and concepts that we would like to explore with you here. I think we would all agree that some of the obvious energy wasters are:

1. Wet insulation in the wall and roof panels
2. Heat lost through the vent lids
3. Venting in general.

Now let us take a closer look at each of these areas:

Wet Insulation

We all know that moisture finds its way into any kiln panel. When moisture does get into the insulation, the insulating value goes down--way down!

We do not have any actual data on kiln panels, however, we do have some data on an experiment we conducted relating to the heat lost through vent lids that is of interest.

Vent Lids

Until fairly recently, I had always assumed that the vent lid transferred heat according to the textbook examples. These textbook examples typically take the approach of dry air on both sides of the aluminum lid. Using this approach, the calculated heat losses are very minimal.

While pondering this question, I recalled moisture dripping from the underside of the vent lids and puddles of water on the fan floor. At about this time, I remembered that it rains a lot in the Northwest.

Could it be that the heat transfer through the vent lid is "Much Greater" than we thought due to "Condensing Vapor" on the inside and rain or snow on the outside?

We put this experiment together in an attempt to find the order of magnitude of heat loss through the vents for various weather conditions:

> Water is boiled in the bottom, vapor condenses on the inside of the sloping roof and collects in the trough and then drained away for measurement.

By measuring the water which is condensed, we will get an indication of heat loss for various conditions.

This chart shows the data from four (4) tests:

Test	H_2O Application	H_2OT	OST	IST	TIME	OZH_2O	BTU/Hr 68'Kiln
	(Std. Calculation)		55	190			14,800
1	Lt.Spkl.,No Runoff	40	55	190	32.5	6.5	20,000
2	Med. Sprinkle	36	50	195	32.5	41.25	125,000
3	Heavy Sprinkle	65	55	190	32	49.5	150,000
4(Thermax)	Heavy Sprinkle	58	50	210	32	-0-	-0-

What this shows is a heat loss much greater than typical calculations would show. The standard calculation for a 68-foot kiln would yield a heat loss of approximately 15,000 BTUs through the vent lid. This data which simulates rain on the roof is approximately 10 times greater than you would calculate using dry air to dry air. It is also interesting to note that Test #4 using insulation reduced this loss to nearly zero. Up to now, we have talked about the energy losses through the walls and vent lids. It is our belief that these losses are substantially greater than you would normally think them to be.

Venting in General

Now let us consider some of the energy losses which take place in the venting of most dry kilns. To start with, let us remind ourselves of how the water in the lumber leaves the dry kiln. Dry air is brought in through the dilution air vent, mixed with the kiln air, and then some of the mixture is exhausted. If things are working according to plan, you remove enough moisture and bring in enough dry air to re-establish the required W.B. depression in order to continue drying. The cold dilution air must be heated up to the kiln temperature in order to hold more moisture and then is exhausted.

The data which I presented last year indicated that approximately 12 percent of the energy consumed in conventional drying goes toward heating up the cold dilution air. In order for any vent system to operate as efficiently as possible, the following must occur:

1. Dilution air entering the kiln must be as dry as possible. If exhaust from one kiln goes into the dilution air vent of the next kiln, many more pounds of air must be passed through the kiln in order to carry the moisture away.
   Air is like a sponge--if the sponge is already half full of water when it comes into the kiln, it will not pick up as much water to carry out.
2. The exhaust air from the kiln should be at as high a wet bulb temperature as possible. The higher the wet bulb temperature, the more water the air can carry.
   Unfortunately, nearly all kilns rely on the kiln fans to accomplish the venting. This means that dilution air is drawn in on the negative side of the fan, and the mixture is exhausted on the positive side of the fan. I doubt that with typical vent locations, the air is thoroughly mixed by the time it is exhausted at wet bulb temperatures much lower than the kiln wet bulb temperature. This means that additional

pounds of dilution air must be passed through the kiln to carry out the water.

Let me remind you that the 12 percent of the drying energy for venting assumed 100 percent efficiency--it could really be two (2) times this amount. As you can see, the venting of the kiln is a very inefficient process, Figure 1. Therefore, we believe much of the discrepancy between theoretical and actual energy required can be found in the venting of the kiln.

To continue this discussion further, let us look at a psychrometric chart, Figure 2.

The controller set points control the conditions of the air entering the lumber. Let us say 170/150. As the air passes through the lumber we have an adiabatic cooling process. Sensible heat is used up in evaporating the moisture. The condition of the air passing through the lumber follows the wet bulb line. Let us assume that at this point of the schedule, we have a 15 degree drop through the load. The air coming out of the lumber is 155/150 or near saturation (90 percent R.H.).

Now the kiln calls for venting. The vents open and 40 degree dilution air enters the kiln chilling the nearly saturated kiln air. We can see that happens when these two air streams mix. The exact location of the mixture condition is determined by relative weights of the kiln air and dilution air being mixed. However, as you see here almost any amount of cool dilution air will bring the mixture over to the saturation line. Since the mixture cannot exceed 100 percent R.H., it will follow the saturation line down, condensing out moisture. The condensing vapor gave up its latent heat to warm the dilution air.

Unfortunately, the moisture has to be re-evaporated, and it causes corrosion problems around the vents and sometimes throughout the kiln.

Conditions which can accent this problem are:

1. Small wet bulb depressions which probably mean the air is saturated as it leaves the lumber.
2. Non-Modulating vents which go wide open then close.
3. Oversize vents which bring a large volume of dilution air into the kiln at one location.

We have a system operating on a kiln which corrects all of the inefficiencies discussed here. We call it the "Vent-X-Changer System," Figure 3.

Dilution air is preheated by the kiln exhaust air. Outside air is drawn in, forced through the control dampers, preheated through the Heat Exchanger and distributed down the length of the kiln. Exhaust air is drawn out of the kiln through the distribution duct, across the Heat Exchanger and control dampers then exhausted out the stack by means of the fan system.

The heart of this unit is an all aluminum finned heat pipe Heat Exchanger, Figure 4. A group of pipes are assembled so that one end of the pipes are located in the hot exhaust duct, and the other end is in the cold dilution air duct. As the hot exhaust air passes over it, much of the heat is transferred to the dilution air.

Each pipe is an individual heat exchanger. The hot air vaporizes the freon inside each pipe, which forces its way to the other end of the pipe. There it condenses out, giving up its latent heat. Then as a liquid, it runs back to the hot end. It is a continuous process requiring no mechanical input.

The Howden finned heat pipe in the VENT-X-CHANGER™ is positioned with one end of the pipe in the hot exhaust duct, and the other end in the cold make-up air duct, so that the air passes over the pipe in a counterflow arrangement.

Each pipe acts as an individual heat exchanger with no moving parts and no external power required.

Each Howden heat pipe used in the VENT-X-CHANGER™, Figure 5, consists of three elements: a sealed all aluminum pipe with integral fins, a capillary wick structure on the inside surface of the pipe, and a working fluid.

Since the pipe is sealed under a vacuum, the working fluid is in equilibrium with its own vapor. Heating one end of the pipe causes instantaneous evaporation of the working fluid in the hot end. The rapid generation of vapor creates a pressure which forces vapor to the cold end of the pipe. The vapor condenses on the cold surfaces and the latent heat of vaporization is transferred.

Now let us go back to the psychrometric chart, Figure 6:

Instead of entering the kiln with 40 degree air, we are now preheating the air to 130 degrees F. This eliminates the condensing, corrosion and a lot of wasted energy.

Now let us talk about some other features of this system:

1. Remember the heat loss out the vent lids? Vent lids are eliminated and all venting is accomplished through a distribution duct system. The vent openings are insulated and sealed.
2. Remember the problem of moist air entering the dilution air vent? We now have one exhaust and one inlet per kiln. These now can be arranged to avoid the air from short circuiting.
3. Remember the problem of relying on the kiln fans to accomplish the venting, and having to exhaust, after the air had been mixed and diluted? Now with a separate vent fan system, exhaust air can be extracted as it leaves the load. Then dilution air is reintroduced in such a manner that:
   a. It is not exhausted before entering the load.
   b. It is heated by the coils before entering the load.

NOTE: This feature is protected by patents held by F.W. Cook and Associates. Other patents are applied for covering other features of the Heat Exchanger and distribution system.

4. Remember the heat required to heat the dilution air (approximately 12 percent of the energy), the majority of this heat now comes from exhaust heat? When you add all these features together into our Vent-X-Changer System, you get a very impressive reduction in energy:

VENT-X-CHANGER PERFORMANCE

Our first Vent-X-Changer has been operating for some time now, and the following data describes its operation and performance.

Dilution air is preheated by heat from the exhaust air. Some typical temperature readings are as follows:

% Flow	Outside Air	Air to Kiln	Air From Kiln	Exhaust
30	56	118	130	102
30	46	124	146	104
70	47	105	116	104

It is interesting to note that because of the counterflow arrangement, air to kiln is hotter than the exhaust.

This system is installed on a single-track kiln with an oil-fired boiler. Oil consumption was monitored before and after the installation of this equipment and the following comparisons were made on similar charges of clear vertical grain cedar.

	Before	After	Reduction	% Reduction
Gallon Oil/Chg.	2,451.00	1,654.00	797.00	32.5
Average Gal/Hr.	4.83	3.26	1.57	32.5

As you can see from these numbers, substantial reductions in energy can be realized with improvements to the kiln-vent system.

The energy saved in drying will:

- Reduce drying costs--especially on gas and oil-fired boilers.
- Increase electrical output on co-generation plants.
- Allow you to accelerate your drying schedules on kilns with limited heat or vent systems.
- Increase drying capacity on boiler limited kilns.

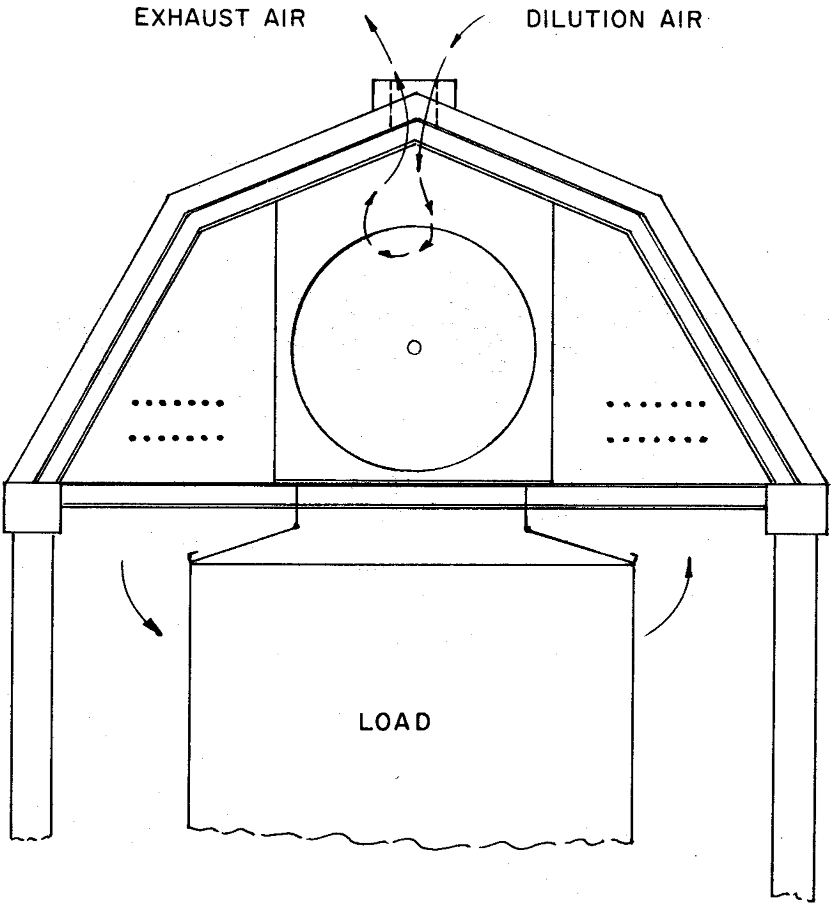

Figure 1. Single track kiln-conventional venting

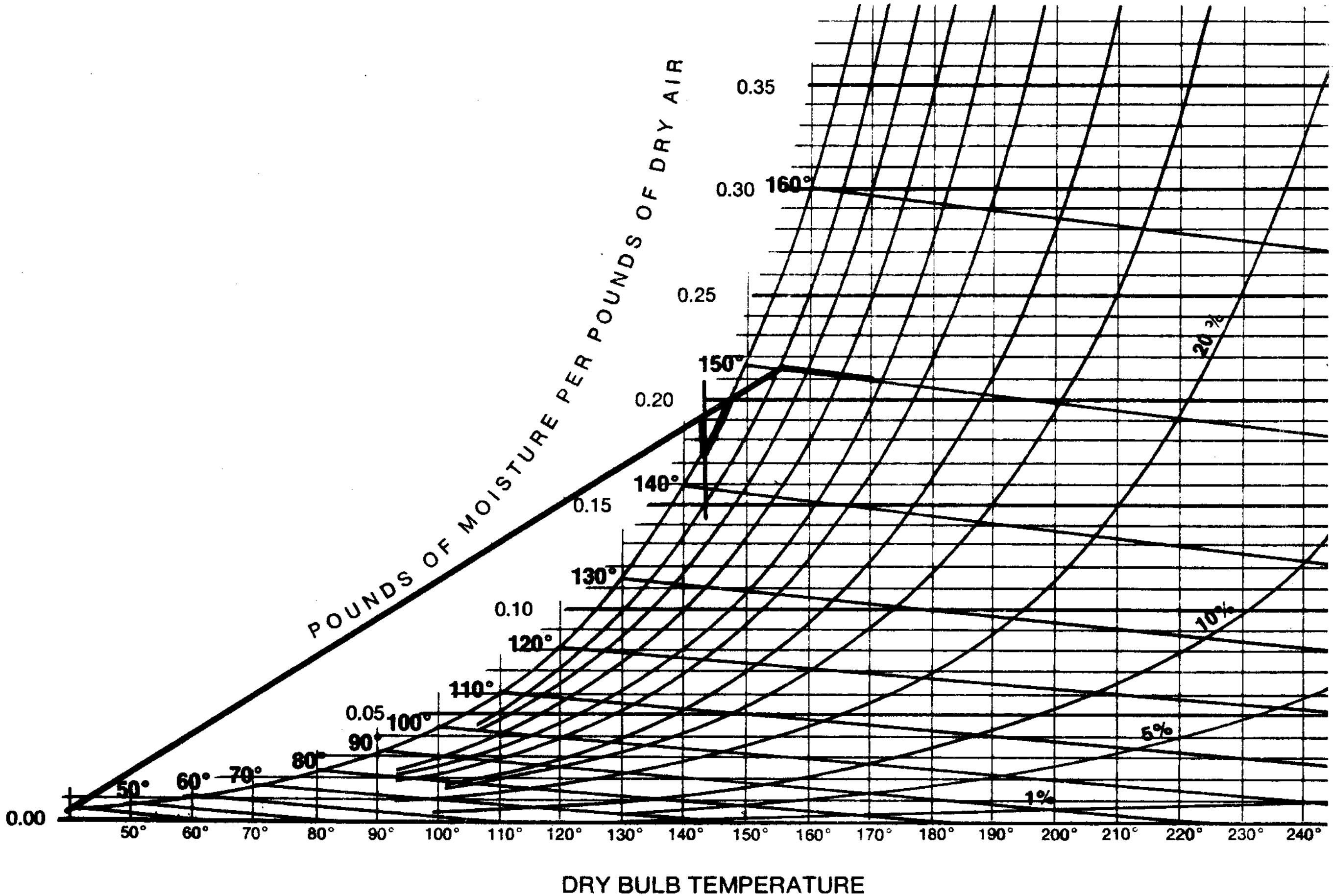

Figure 2. Psychrometric chart

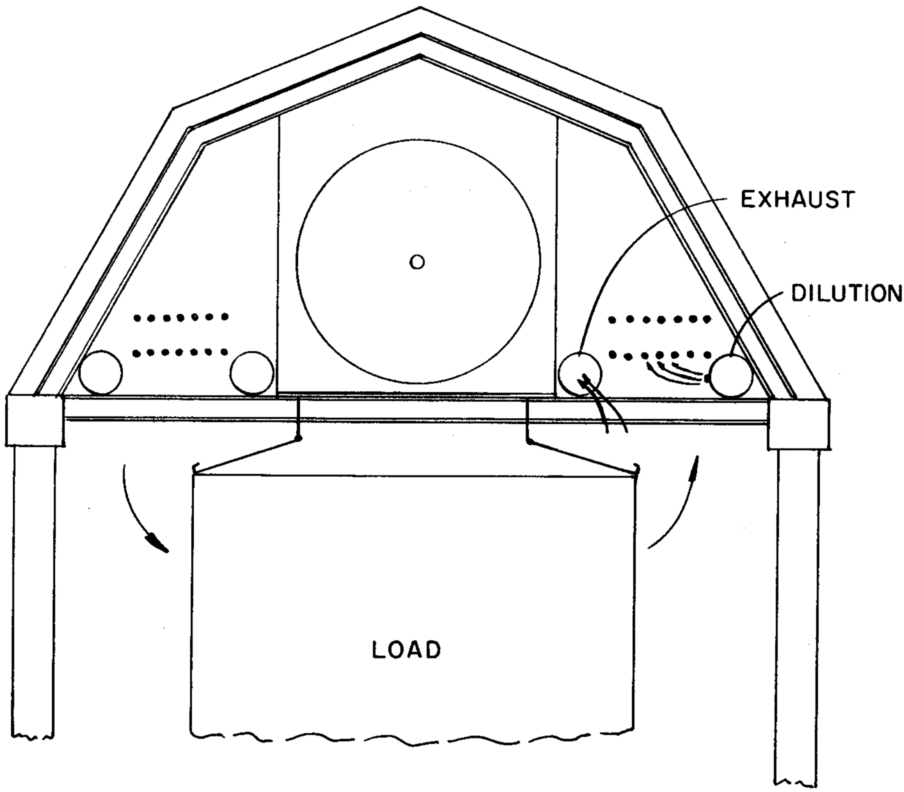

Figure 3. Single track kiln with Vent-X-Changer system

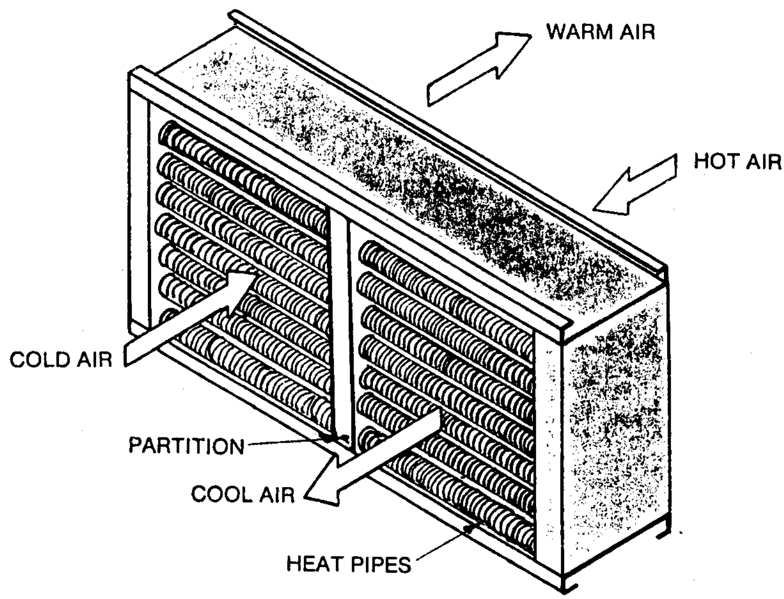

Figure 4. Heat exchanger unit

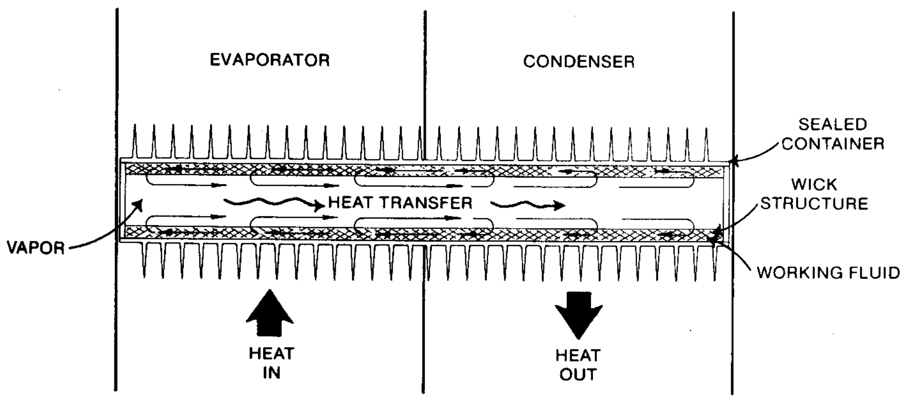

Figure 5. Vent-X-Changer

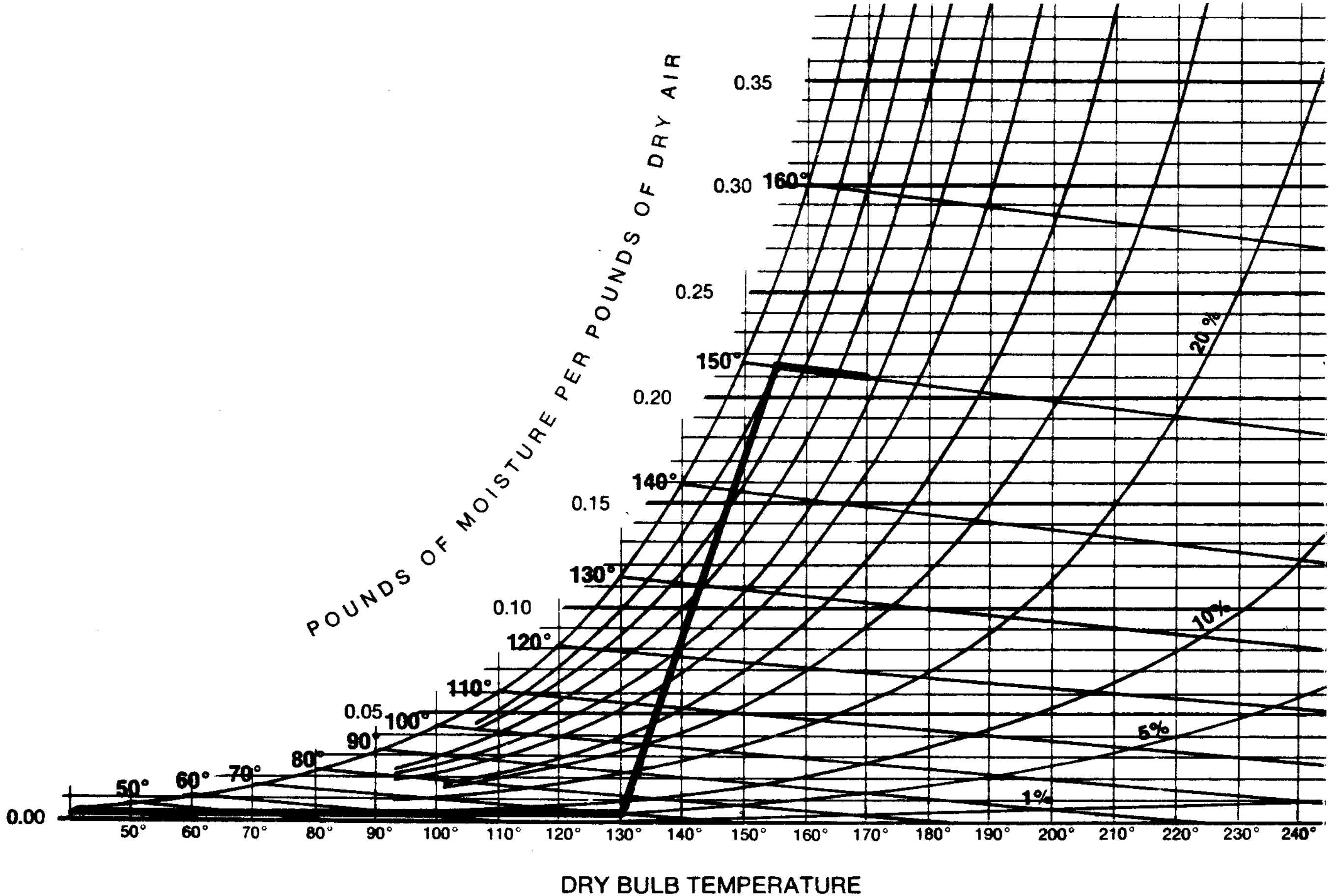

Figure 6. Psychrometric chart