

# CORRECTION OF PROBLEMS ENCOUNTERED WITH STEAM HEATING SYSTEMS

William M. Hanley  
F. W. Cook & Associates, Inc.  
Portland, Oregon

## Introduction

First, I want to correct what may be a misleading impression caused by the above title. It will not be possible for me to present here answers to all problems with steam heating systems. I will attempt to cover certain areas of this subject where our experience has shown there is a need for improvement in many commercial lumber dry kilns.

A number of excellent talks have been given at earlier annual meetings on related subjects. These include the need for good temperature control in dry kilns, information on the properties and physics of steam, operation and maintenance of steam traps and other subjects.

## Desirable Features of Heating Systems in Dry Kilns

The desirable features listed below are not limited to steam heating systems but are applicable to any medium for heating in lumber dry kilns.

1. The initial installed cost must be reasonable. Unless the equipment is competitive in cost with other comparable equipment, it will find only limited use in commercial dry kilns.
2. The heating equipment should have the capability of attaining the desired temperatures and maintaining uniform temperatures throughout the dry kiln.
3. Required maintenance should be minimal.
4. The operational cost per unit quantity of lumber dried should be minimal or at least competitive with other heating systems.

From a standpoint of optimum performance, the ideal steam heating coil would be quite small, say 8 feet in length, with a separate steam flow control valve, feed line, drain line and steam trap. However, this would not be practical from the standpoint of either the initial cost or minimum maintenance.

On the other hand, if the heating coils are overly large, or if the feed lines, diaphragm valves, drain lines and traps are inadequate, the heat transfer from the coils will be reduced.

## Component Parts of a Steam Heating System

The different components that make up a steam heating system can be listed as:

1. A steam supply source includes a boiler plant, steam lines to and a supply header across or near the dry kiln.
2. Steam flow control valves, usually referred to as diaphragm valves, although they can be other than pneumatically actuated diaphragm valves.
3. Steam feed lines from the supply header to the control valves, and to the different heating coils.

4. The heating coils themselves.
5. The drain lines on the different coils and steam traps to handle condensate from the coils.
6. A condensate collecting system and pumping unit to return the condensate from the kilns back to the boiler plant.

The major cost for the heating system within the dry kiln is for the heating coils, so consideration must be given to obtaining the maximum heat transfer capability from the coils. This discussion will focus on the heating coils, flow control valves and steam feed lines.

#### Configurations of Heating Coils

Briefly, some of the configurations of coils used are:

1. Return bend overhead coils.
2. Inclined prefabricated panel overhead coils.
3. Blast type overhead coils.
4. Ell shaped booster center coils.
5. Prefabricated panels with vertical lines of pipe in center coils.

The three overhead coil designs mentioned are shown by a sketch in Figure 1. Each configuration or design does have certain advantages and disadvantages as compared to the others.

#### Factors That Affect Heat Transfer From Heating Coils

Let us look at the factors that affect heat transfer from steam in the heating coils to air circulated across them. First, we will assume that the pipe making up the coils is kept filled with steam only and that condensate is removed as rapidly as it is formed. Second, air is circulated transversely across the outside of the pipe coils. For practical purposes we can also say all heat transfer takes place by convection of the air circulated across the outside surfaces of the pipe.

1. The heat transfer rate will vary with the air velocity across the outside of the pipe. According to curves shown in one handbook, with all other factors consistent, doubling the air velocity across the pipe will increase the heat transfer rate about 60%.

2. The heat transfer rate per square foot of heating surface will vary dependent on the materials used. The square feet of heating surface per lineal foot of pipe will vary with the diameter of the pipe or tubing, the diameter and spacing of fins along the length of the pipe.

Steel finned pipe has a considerably higher heat transfer rate per lineal foot than plain steel pipe. The various combinations of copper and aluminum finned tubings have higher heat transfer rates than comparably sized steel fin pipe, but their cost for equivalent heating capacity is usually higher than for steel.

It would be convenient if the manufacturers of finned pipe and tubing used a uniform method for rating the heat transfer of their different designs of finned pipe and tubing. Several manufacturers supplying coils in the air conditioning industry rate their finned tubing on the basis of heat transfer in B. t. u. per hour per square foot of surface area per degree temperature difference between steam and air at a stated air velocity. We will refer to this as a "U" factor. From field test work we have determined "U" factors for various types of finned pipe, in different configuration heating coils and in dry kilns with different rates of air circulation.

3. The heat transfer rate (by convection) is directly proportional to the difference between the temperature of the steam in the coil and the air temperature across the outside of the coil. We will refer to this as a "K" factor. Curves for "K" factors with varying steam pressure and ambient kiln temperature are given in Figure 2.

When designing and sizing the other components for the heating system, it is necessary to determine the steam flow to the heating coils. The maximum steam flow to the coils is equal to their condensing capacity. The condensing load in pounds of steam per hour is equal to the lineal feet of pipe in the coils times the appropriate "U" factor times the "K" factor for the steam pressure and kiln temperature conditions.

Up to this point we have tried to provide background information pertinent to two areas for improvement in most existing dry kilns. The remainder of this talk will be in regard to:

1. Modulating steam flow control valves.
2. The effects of pressure drops in the steam feed lines to the heating coils.

However, we do not want to leave the impression that other design features are not important and necessary. These include maintaining the design steam pressure to the supply header, having adequate heating coils for the particular drying requirements, properly drained coils and properly sized and operating steam traps.

#### Modulating Steam Flow Control Valves

Modulating (or proportioning, throttling) type valves can be explained as opposed to "on-off" valves. The older practice was to use on-off steam flow control valves for the heating coils. The on-off valve is just that - it is either full closed or full open on an air signal from the controller instrument. The modulating type valve will be open a greater or lesser amount depending on the heating demand to maintain the desired set point temperature. The modulating valve is actually a pressure reducing valve, controlled by a varying air signal pressure from the controller instrument.

Some of the advantages for the modulating type valve are elimination of the cyclical variation in the dry kiln temperatures as recorded by the instrument and considerably more uniform temperatures in the length of the dry kiln which will not be shown by the recording chart. The steam demand will vary erratically with on-off valves. The boiler, particularly if it is waste-wood fired, probably will not be able to operate within the pollution control requirements. Modulating valves will smooth out the steam demand and the firing rate for the boiler plant to meet that steam demand, often with dramatic results.

The design requirements for modulating valves with dry kiln heating coils are not sophisticated or exotic. In a number of cases it has been practical to utilize existing on-off valves and convert them to modulating control to save the cost of new valves. Most existing recorder-controller instruments in use on dry kilns today can also be used with some minor changes for modulating control.

It is important that the valves be properly sized.

#### Pressure Drop in Steam Feed Lines

When steam flows through a pipe, or line, there will always be some reduction of pressure in the length of the line. The amount of pressure drop will vary with:

1. The flow rate. The higher the steam flow, expressed in pounds of steam per hour, the greater the pressure drop will be through a particular section or length of pipe.

2. The size of the pipe will have a marked effect on the pressure drop. For example, assuming a flow of 2,000 lbs. per hour for steam at an initial pressure of 100 psig., the pressure drops through lengths of 100 feet will be 40 psi. for 1-1/4" pipe; 15 psi. for 1-1/2" pipe; and only 5 psi. for 2" pipe.

3. Short changes in direction or area through fittings and hand valves account for a large part of pressure drops. For instance, the resistance through a globe valve is about 40 times the resistance in equivalent feet of pipe as through a gate valve. The resistances for various size and type fittings and hand valves in equivalent feet of pipe of the same diameter are listed in several manufacturers hand-books or catalogs.

#### Effect of Pressure Drop in Feed Lines to Heating Coils

The recording chart, Figure 5, shows the effect of an excessive pressure drop in the feed lines on the ability of the heating coils to attain the desired temperatures in the kiln. The amount of pipe in the coils of the kiln was adequate, the steam traps were performing, the diaphragm valves were fully open, but the temperatures in the kiln were below the set point temperature. The problem was that the feed lines to the heating coils were too small. With 90 psig. supply pressure, the calculated pressure drop to the heating coils was 50 psi., or the pressure in the coils was only 40 psi. The coils, which were of the return bend type, were checked and it was found about one half the lineal feet of pipe in the coils was cold when the air temperature in the kiln was about 100°F.

Another recording chart, Figure 6, is quite typical. One end of the kiln is slower to respond in temperature, and at certain parts of the drying schedule will not maintain the desired temperature. This is caused by a greater pressure drop in the longer lengths of feed lines to the coils at the far end of the kiln from the control valves.

#### Effect of Pressure Drop Differential Between Multiple Coils

I want to quote directly from an article in a manufacturer's catalog. The catalog has an illustration of two identical unit heaters, both connected to a common feed line and with the drain lines from the two heaters connected into a single steam trap.

The article states, "If more than one drain point is connected to a single trap, condensate and air from one or more of the units may fail to reach the trap. Any difference in condensing rates will result in a difference in the steam pressure drop. A pressure drop difference too small to register on a pressure gauge is enough to let steam from the higher pressure drip point block the flow of air (or even condensate) from the lower pressure drip point. The net result is sluggish heating, reduced output and fuel waste."

The sketch, Figure 7, shows three overhead coils on one side and one end of a single track kiln 104 feet in length. The recording chart didn't indicate anything drastically wrong, but the loads at the far end of the kiln came out wet. It was found the far end coil was water-logged. A three coils are on a common steam feed line and with their drain lines

connected to a common trap. The pressure drop through the feed lines prevented the coil from draining. The problem was corrected by installing a larger sized feed line to the far end coils. It could also have been corrected by installing a separate trap for the far end coil, but this was the less desirable solution in this case.

#### Check to Determine if All Coils Are Heating

Here is a check that will prove without question if the heating coils in your dry kilns are performing to their full potential. If possible, fill the kiln with green lumber loads. Leave the doors and ventilators open. Turn the heating coil hand valves and diaphragm valves full on. Blow down the steam traps to purge the coils of air. Feel all the coils with a water soaked rag. Chances are you will find all the lines of pipe in the coils are hot and will sizzle the water on the rag.

Next, turn the fans on so air is circulating across the coils. Be careful to stay away from the fans and you may have to lay down planks for access to the coils. After the fans have been on for about five minutes, feel the lines of pipe again with the wet rag. It won't be difficult to say whether a section of pipe is hot or not - it will either be hot or cold. Mark any cold areas with a white chalk for future reference. The chances are you will be surprised to find that a considerable proportion of the heating coils are cold.

#### Rules for Sizing Control Valves and Feed Lines

Based on our own experience for what has proven to work satisfactorily, we have adopted some rules for our sizing of steam flow control valves and feed lines to the heating coils. Steam flows in lbs. of steam per hour are based on the condensing rates for the heating coils using the design steam supply pressure and an ambient air temperature in the kiln of 100°F.

1. The modulating flow control valves are sized so the maximum pressure drop through a full open valve is 10% of the design steam supply pressure.

2. The feed line piping and fittings are sized so the total pressure drop from the supply pressure to the heating coil, including the pressure drop through the flow control valve, will not exceed 20% of the design steam supply pressure.

3. The piping and fittings in the feed lines between the various heating coils with common feed and drain lines are sized for only 1% pressure drop differential from inlet of first coil to inlet of last coil in the steam flow. Perhaps this requirement is more stringent than necessary, but good results have been obtained with its use.

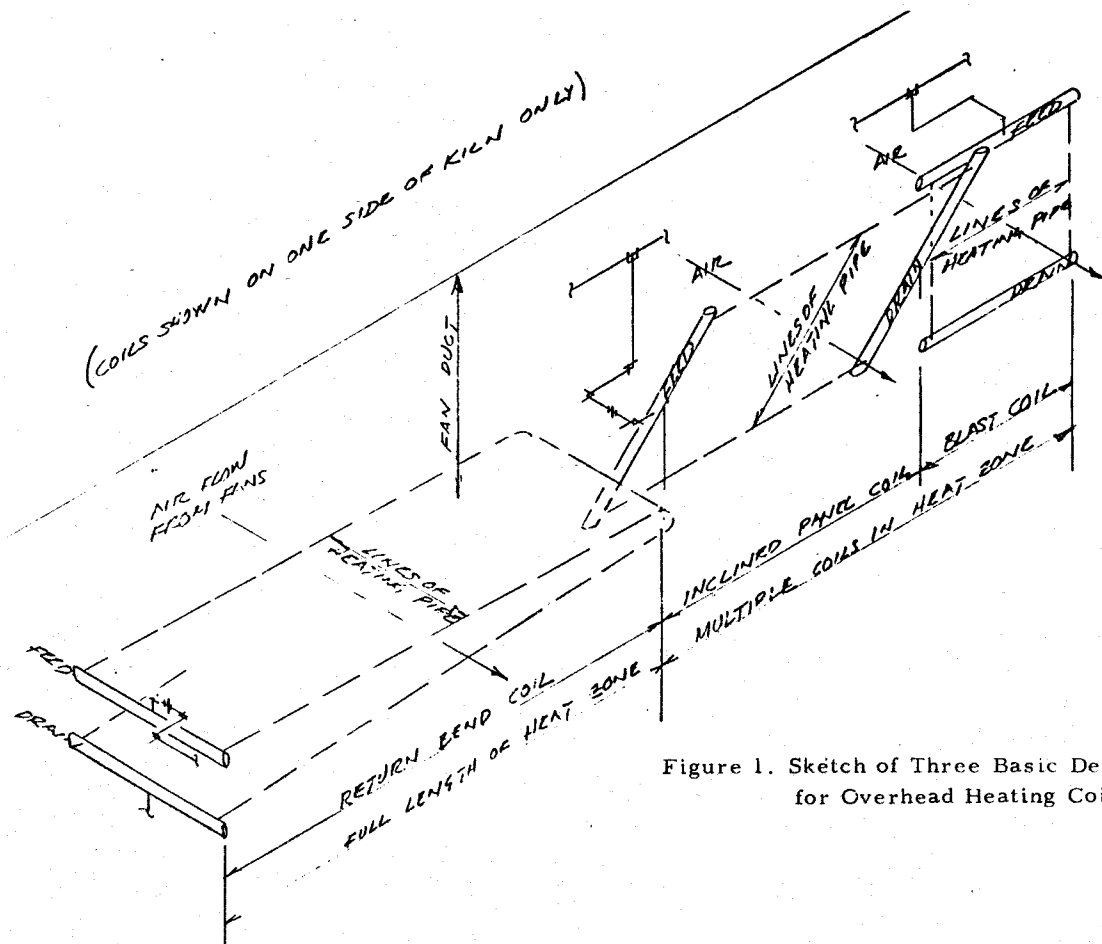


Figure 1. Sketch of Three Basic Designs for Overhead Heating Coils.

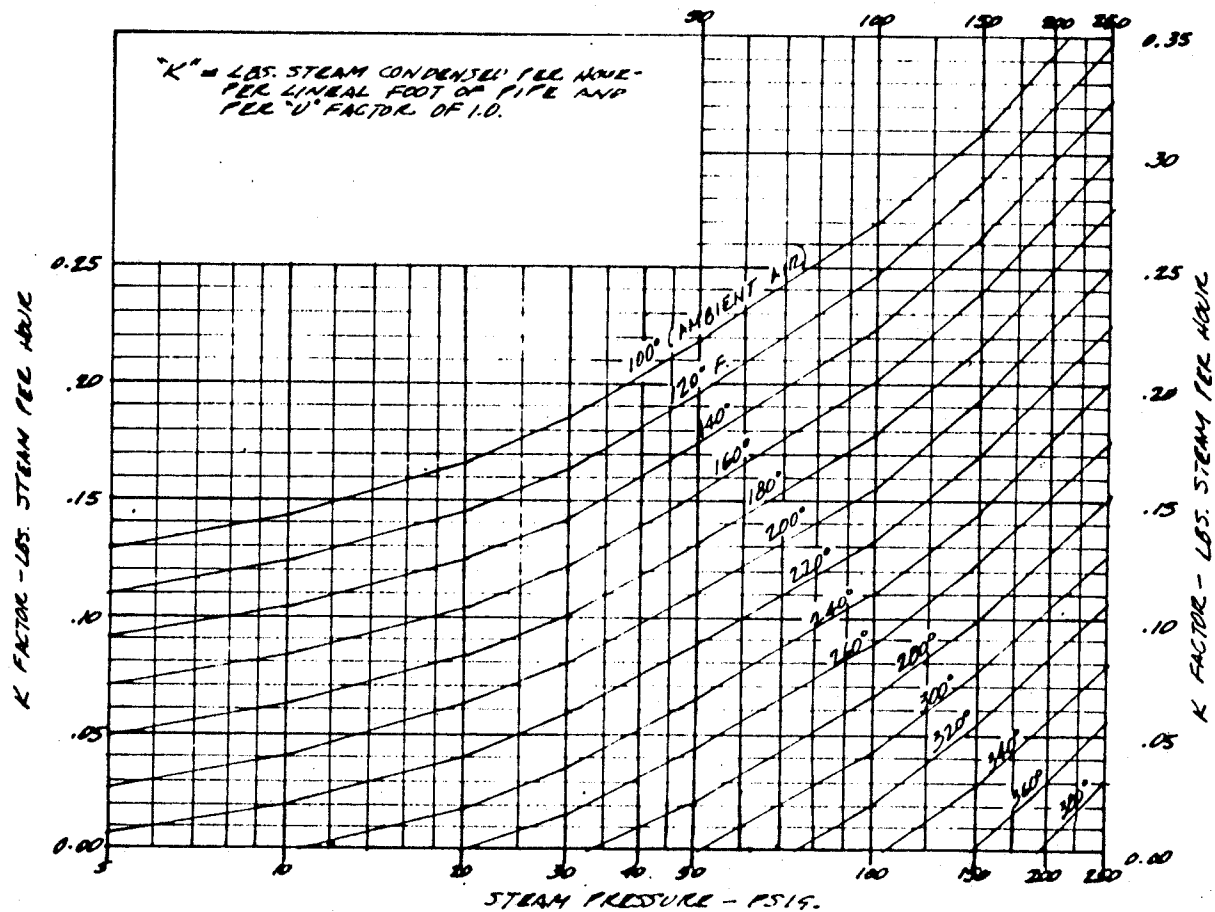


Figure 2. "K" Factor Curves with Varying Steam Pressure and

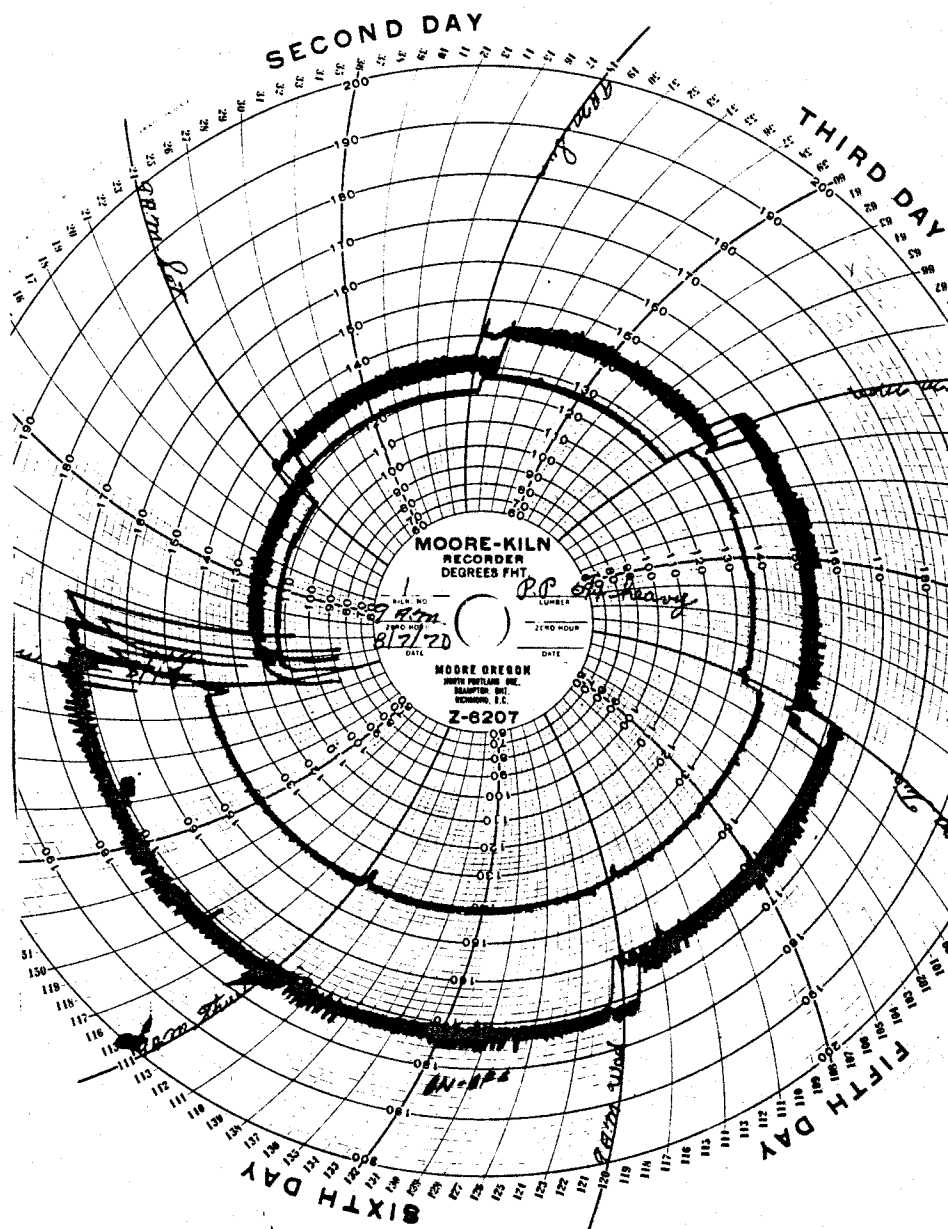


Figure 3. Recording Chart from Dry Kiln with On-Off Control Valves.



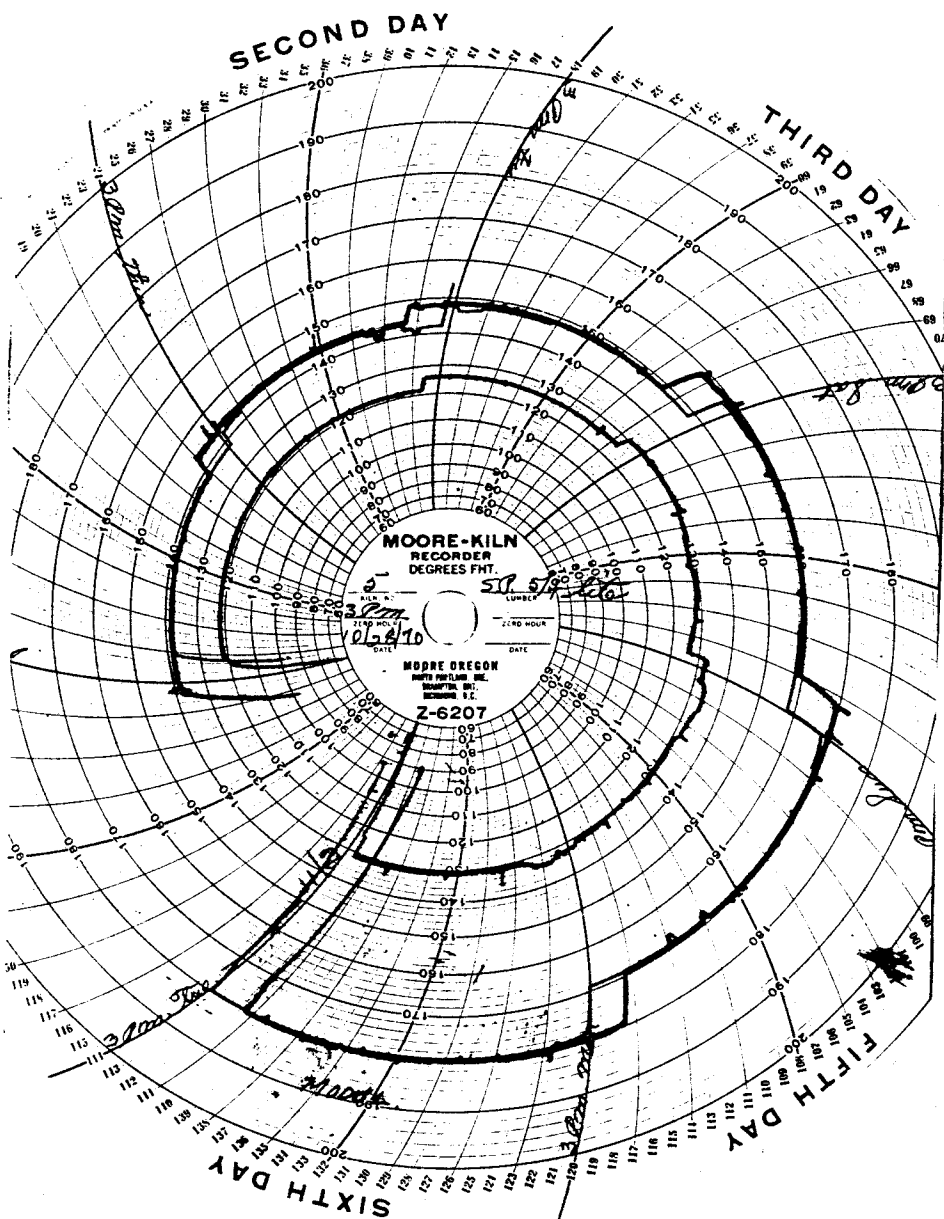


Figure 4. Recording Chart from Dry Kiln with Modulating Control Valves.

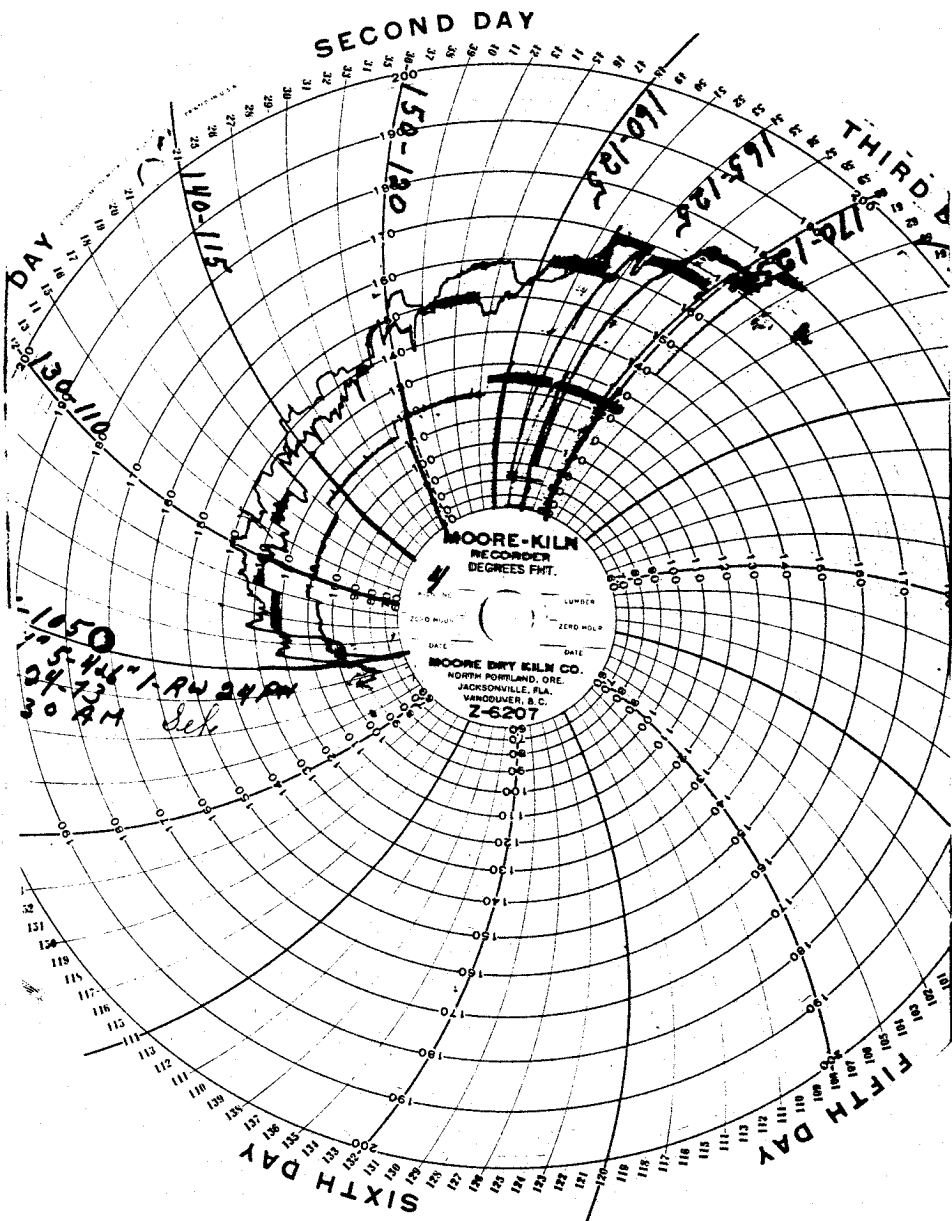


Figure 5. Recording Chart from Dry Kiln with Insufficiently Sized Feed Lines to Heating Coils.

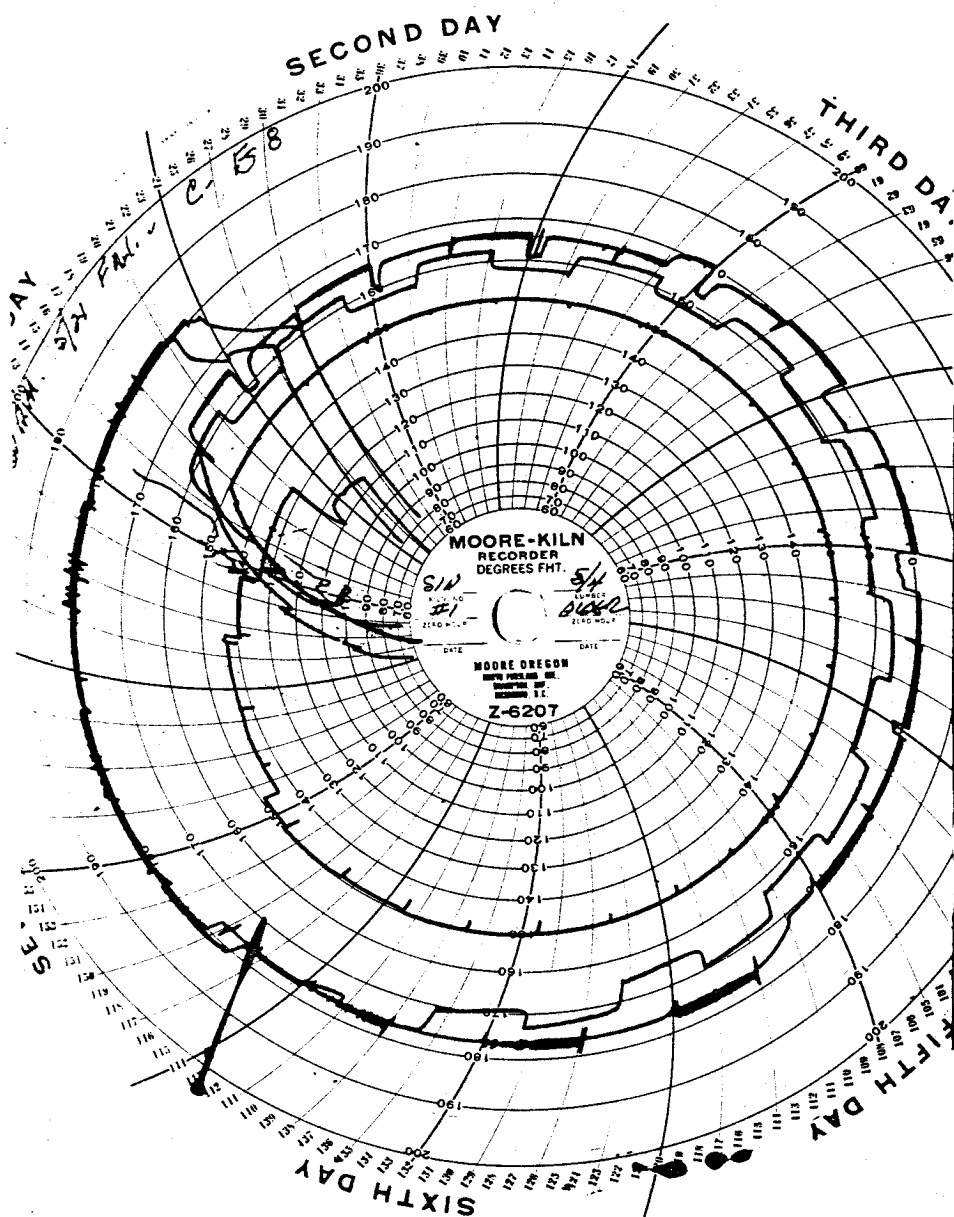


Figure 6. Recording Chart from Dry Kiln. Temperature at Far End Slow in Responding

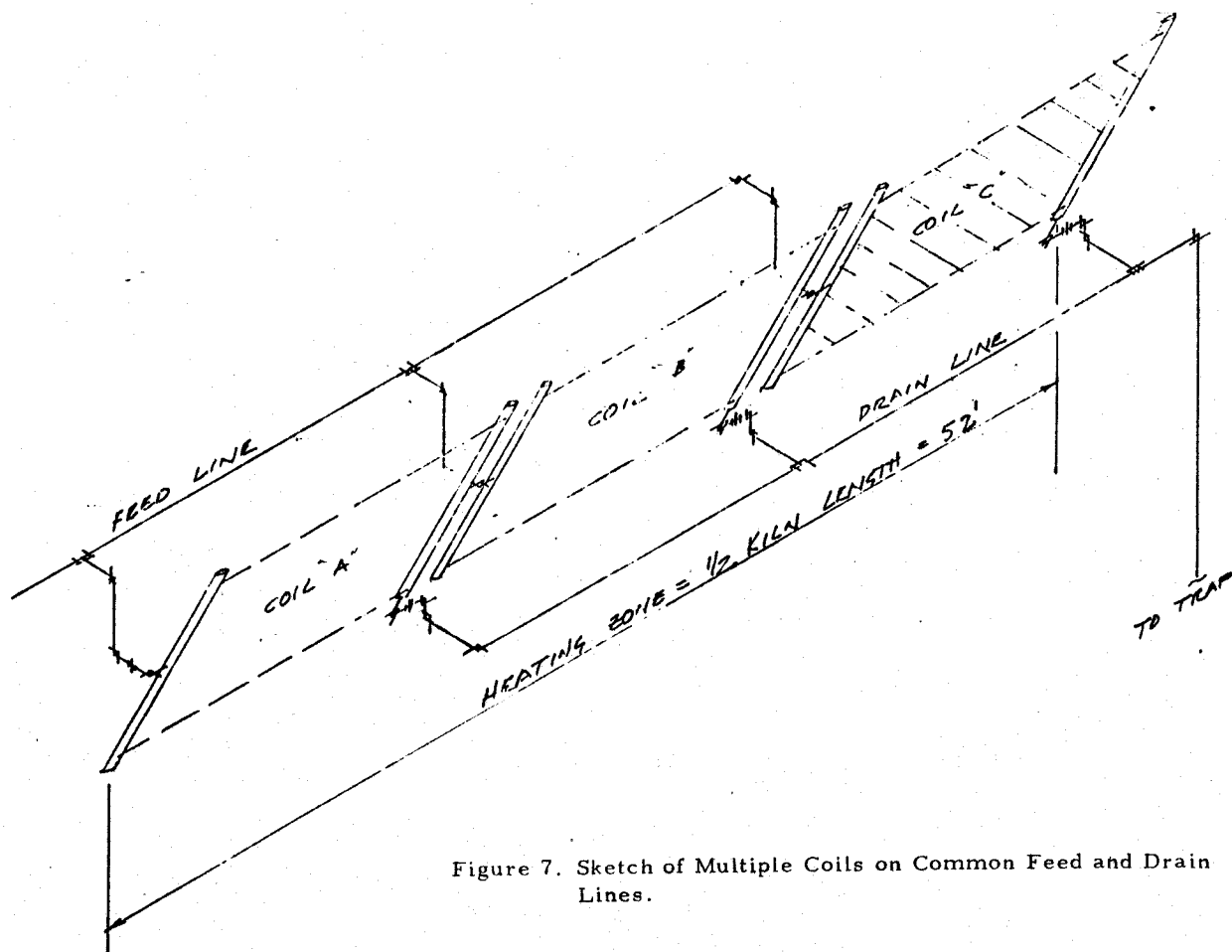


Figure 7. Sketch of Multiple Coils on Common Feed and Drain Lines.