TESTING COMMERCIAL KILNS FOR UNIFORMITY OF DRYING CONDITIONS

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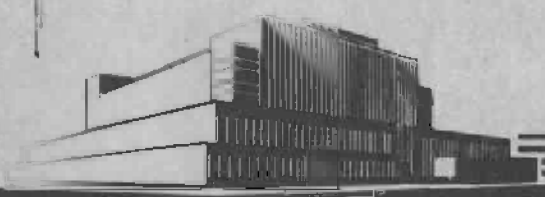

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

TESTING COMMERCIAL KILNS FOR UNIFORMITY OF DRYING CONDITIONS

By

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In the kiln drying of lumber, perfect kiln control is desirable to maintain the most uniform drying conditions. Although perfect control may never be attained some of the problems influencing kiln control that frequently arise can usually be solved if the performance of the kiln is constantly checked in order to assure maintenance of the desired drying conditions.

Preliminary Inspection of Commercial Kilns

Time may be saved during the testing of a commercial kiln for uniformity of drying conditions if such items in the kiln as coils, traps, valves, vents, walls, ceiling, and doors, as well as the methods used in piling and loading the kiln cars, are thoroughly examined before the test run is started.

Coils

The heating coils in the kiln should be examined for any leakage. Their general lay-out should be arranged so that there is ample drainage of the condensate throughout the entire length of the coils. These important features of the heating system can be easily examined in a short time.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Traps

Along with the heating system, the traps should be checked in order to insure proper heating from the coils. Trap action can be easily checked by observing the discharge from the by-pass valve or test valve located on the trap.

Valves

All valves on the kiln should be checked before use to make sure there is no leakage of steam through any of them. A slight leak in any of the control valves is likely to cause a rise in temperature at the header end of the coil and may allow the kiln temperature to coast above that desired. A leak in the steam-spray control valve may cause the relative humidity or the temperature in the kiln to become excessively high.

Vents

The ventilating system of most dry kilns is operated in connection with the steam-spray lines. An inspection of the vents should be made in order to be sure that automatic vents are opening and closing at the proper times. The vents should be further checked to make certain that they close completely and that their flapper covers fit well.

In various nonautomatic venting systems, the aspirators, flues, and intake openings should be checked to insure removal of the excess moisture released in the kiln during the early stages of drying.

Walls and Ceiling

The kiln structure should be checked for possible air leaks. Open mortar joints, openings around I-beams, and leaky roofs are some sources of air leakage or infiltration that may upset the temperature distribution.

Doors

In both natural-draft and forced-circulation kilns, any air leakage or infiltration about the doors may influence the temperature near the door end of the kiln. For this reason, the doors should be kept as tight as possible so that leakage or infiltration and consequent temperature-gradient upset will not retard the drying in this zone.

Kiln Charge

A general inspection should be made of how the lumber is piled onto the kiln cars and of how the cars are loaded into the kiln. Variation in piling and loading may cause differences in air circulation and thus give inconsistent results in comparing different runs in the same kiln.

Methods of Checking the Longitudinal Temperature Range

In order to dry lumber successfully in a dry kiln, the temperature range in the longitudinal direction of the kiln must be kept under close control. The longitudinal temperature range is measured in locations, or zones, that vary according to the type of dry kiln employed. The locations in which the temperature measurements should be taken are determined by the method employed to circulate air, the direction of air flow, the location of fans or blowers, and by the coils, vents, and methods of lumber piling used. For example, in a cross-flow, single-track, reversible-fan kiln, the temperature measurements should be taken at intervals along the kiln on the entering air side of the loads. In a natural-draft, end-piled kiln, temperatures should be measured in the air stream at intervals on the longitudinal side of the load near its top, and also in an open flue one or two feet from the side of the load and approximately two feet above the rails.

Hot and Cold Zones

All references in this report to so-called hot and cold zones in the kiln are to the zones of relatively high and low temperatures on the entering-air side of the load.

The first step in the inspection of a kiln is to determine where the hot and cold zones are located. It is necessary to know the locations of these zones not only from the standpoint of the temperature range in the longitudinal direction, but also because they aid in determining the proper location for the controlling bulbs in the kiln.

Thermometers

Thermometers of the maximum-reading type may be used in determining the hot and cold zones in any kiln, but, if so used, certain precautions must be followed. Since the temperatures taken must be in the entering-air zone, the thermometers must be placed so that they record the entering-air

temperatures. Care must be used to avoid jolting these thermometers, as the mercury column can be very easily shaken down. Jolting the instrument may cause errors in readings of as much as 3° to 5° F. The thermometers should be left in the kiln for at least 20 minutes in order to be sure that the peak temperature has been reached. In using a maximum-reading thermometer, the operator does not have to remain in the kiln during the readings.

If an indicating thermometer is used, the operator must remain in the kiln during a number of oscillations of the temperature. This can be very uncomfortable and is not recommended if temperatures are as high as 140° F.

Suggested placement of the thermometers is discussed later in connection with the placement of thermocouples in the kiln.

Thermocouples

Another means of taking the longitudinal temperature range in a dry kiln is by the use of a potentiometer and thermocouples. Because of its ease of operation and accuracy, if correctly used, this method of obtaining instantaneous temperature readings is recommended. Since, during the taking of any temperature reading by this method, the kiln conditions are not altered by having to open doors or shut down the kiln in order to either remove or read the thermometers, the method is highly desirable.

Thermocouple cables.--In order to wire a dry kiln with thermocouples and to lead the wires out of the kiln to the potentiometer, it is of advantage to build a cable. This cable may be of any length and contain as many thermocouples as are necessary. A method of making a 50-foot cable with a pair of thermocouples spaced every 10 feet is shown in figure 1A. In making the cable, the tape should be kept at least 1/4 inch back of the contact point between the copper and constantan wires. The operator should check the cable occasionally to see that the tape does not slide over the wires at the contact point, because errors of as much as 7° F. below true temperatures may occur if this point is covered by the tape.

The wire used in making up a cable should be enameled and cotton-covered, and be at least 20 gage in size. Any wire that is smaller than 20 gage, although it is more sensitive to temperature changes, will not stand rough handling. The wires must be given a further treatment with a water-resistant material to prevent short circuits in the system due to moisture. Satisfactory moisture retardants are pitch, asphalt, and some pliable plastics. This coating material must have a softening point above the highest temperature in which the cable is to be used, and it must also be sufficiently pliable to prevent cracking or checking.

A common constantan wire can be used for each pair of thermocouples (fig. 1B). If the common constantan wire becomes shorted or broken, however, both thermocouples are out of order. This means that a check of the condition of the constantan wire should be made when a pair of thermocouples shows erratic readings. The cost of the cable is greatly reduced if made in this manner, since only one-half the constantan wire is used that would be used if each thermocouple were wired independently.

All thermocouples should either be welded or soldered. Rosin-core solder must be used, for acid-core solder will induce an electromotive force great enough to cause a noticeable error in temperature readings.

Placement of thermocouples or thermometers in forced-circulation kilns.--The placement of thermocouples or thermometers in the kiln is determined by the selection of a longitudinal plane on which temperature readings are to be taken. In forced-circulation kilns the first thermocouple should be placed 5 feet from the door and others at intervals of approximately 10 feet along the length of the kiln in the entering-air stream. Where reversible circulation is employed, thermocouples should be installed on both sides of the load directly opposite each other. By wiring the kiln in this manner, entering-air temperatures can be studied regardless of the direction of air circulation. Methods of wiring are shown in figures 2 and 3. Forced-circulation kilns that are charged with lumber piled with an "A" flue through which the air enters the load, must be wired so that temperature readings can be taken in the flue (fig. 4). The thermocouples are spaced as in the other kilns. The location of the thermocouples is such that one line is located in the "A" flue in positions approximately 6 to 8 inches above the bottom of the flue, and another line is located in corresponding positions outside of the load. Temperatures must be obtained and compared from both tracks in double-track "A"-flue and plate-type kilns to obtain the longitudinal temperature range.

Data obtained in a transverse-duct, external-blower kiln show that extreme variations in entering-air temperatures occur from end to end of the transverse ducts as well as between individual ducts.

A suggested method for placement of thermocouples in a kiln of this type is shown in figure 5. It requires two cables, one strung along each end of the loads. The thermocouples on the outside of each load can be used if desired, but are not essential as they determine only leaving-air temperatures. The thermocouples in the "A" flue must be located in a high air-velocity zone, approximately 6 to 8 inches above the bottom of the load, and approximately 12 to 18 inches in from the ends of the load. They should not be placed directly over the rails or other obstructions that would interfere with the air velocity.

Placement of thermocouples or thermometers in natural-circulation kilns.--Natural-circulation kilns are wired in a slightly different manner than are the forced-air kilns (fig. 6). One line of thermocouples, spaced as in the forced-air kilns, is placed near the top of the load, with the junction extending into the air stream. Another line of thermocouples is placed directly under those in the top line, but these junctions are placed in the load proper approximately 18 inches from the bottom and in the second or third flue. Care must be taken to insure that the thermocouple does not touch the wet lumber. As the circulation may change during the drying, the kiln temperature will be determined by either the lower or upper row of thermocouples, whichever shows the higher average temperature. In general, except in the final stages of drying, the upper row of thermocouples will show a higher temperature than those in the lower row. Occasionally, one or two thermocouples in the lower row may show higher temperatures than those in the upper row during some of the stages of drying. If this occurs, the higher readings obtained from thermocouples in the lower row should be disregarded and only those of the termocouples in the upper row should be used for the determination of entering-air temperatures. Such discrepancies in the circulation may be caused by irregularities in the flues in the lumber pile or by irregularities in the radiation. In the final stages of drying, the lower row of thermocouples will, in general, be the hotter and their readings should be used as entering-air temperatures.

Placing maximum-reading thermometers in a kiln by means of a cable.--Maximum-reading thermometers, if they are placed in the same locations as suggested for the thermocouples, may prove very satisfactory as a means of taking temperature readings in a number of locations in some types of kilns without going into the kiln. This method requires the mounting of a pulley at each end of the kiln on the inside wall in the entering-air stream. A continuous cable of either wire or rope is then put in place. Hooks from which thermometers may be hung, are attached to this cable at intervals. In this fashion the thermometers can be placed in their respective positions in the kiln by merely rotating the cable. In kilns that have only one door and are not more than 50 feet long, this will work satisfactorily. In kilns longer than 50 feet, however, some means may have to be devised in order to control the sagging of the cable. In 100-foot kilns with a door at each end, two cables, one from each end to the center, will suffice.

Shielding from direct radiation.--No matter what type of temperature-measuring device is used, it should be shielded from any direct radiation whenever such radiation may influence the accuracy of the readings. An efficient method of shielding a thermocouple from direct radiation is shown in figure 7. A small strip of cardboard approximately 1-1/2 inches wide is used. The thermocouple is inserted through a small hole and is thus shielded from the direct heat rays.

Causes of erroneous thermocouple readings.--A thermocouple and potentiometer combination is not infallible, and will give incorrect readings under certain conditions.

For example, temperature changes within a potentiometer will give incorrect readings. If a potentiometer is exposed to a changed temperature condition, it should remain exposed to the new temperature long enough to reach equilibrium before any readings are taken. The balance of the potentiometer will become stable when the temperature of the compensator attains the temperature of the surrounding air.

Potentiometers will not operate when their own temperature is below 40° F.

Potentiometer balance is an important item to check during every set of readings. Before taking a series of readings, and during the series, the balance of the potentiometers should be checked according to the instructions that accompany the instrument. A potentiometer will not give accurate readings when it is out of balance.

Potentiometer warm-up periods must be allowed before any readings are taken. Erroneous potentiometer readings may result if they are taken immediately after the potentiometer switch is closed. Such readings are invariably too low, sometimes by as much as 8° F. When readings are taken immediately, this low reading affects the actual differences in the thermocouple readings (because the last of the series may be correct readings), and also the total difference from early to late readings. For these reasons, the switch to the thermocouple-potentiometer circuits should be closed about 3 minutes before the potentiometer is balanced or any readings are taken.

Cold drafts also affect the readings. If a cold draft should strike either the jack box or the potentiometer, erroneous readings for a part of the series may occur. The possibility of such drafts striking the equipment can be easily eliminated.

Thermocouples touching the lumber also cause erroneous readings. In the early stages of drying, the temperature of the lumber is lower than that of the surrounding air. Also due to the rapid evaporation of water, if the thermocouple is too close to or touches the lumber, wet-bulb temperatures may be read in place of dry-bulb temperatures. Therefore, when the temperature of the drying atmosphere is sought, the thermocouples should not come in direct contact with the lumber.

An erroneous temperature reading may result from the thermocouple effect induced at the jack box if precautions are not taken. A jack box and plugs are commonly used as a means of switching from one thermocouple location to

another (fig. 8). At the point where the constantan lead from the potentiometer attaches to the brass fitting of the plug (point a, fig. 8) and at the point where a constantan lead from the kiln attaches to the brass fitting of a jack (point b, fig. 8), such contact between dissimilar metals becomes, in itself, a thermocouple. The body heat of the operator as he touches the plug will cause a difference in temperature between thermocouple (a) and thermocouple (b) and will throw an error into the temperature readings shown by the potentiometer for the thermocouples located in the kiln. Such error can be avoided easily by insulating the exposed metal parts of the plug, or by taking care that one's fingers do not touch the metal parts of the plug.

Moisture accumulation in any section of the cable may cause short circuiting and result in erroneous readings. Avoid kinks in the cable, support it by loops of tape or rope rather than on metal hangers, and avoid laying it anywhere where friction or abrasion may damage it. Keep the cable away from areas of condensation along the walls and out of puddles. If possible, run the cable out of the kiln through an insulated hole rather than through the condensate that commonly collects near the kiln door.

Temperature Cycles in a Dry Kiln

Heat is supplied in most kilns by a thermostatic system of control. Thermostats, by intermittently opening and closing a steam valve, control the amount of steam entering the heating coils, but after the valve is closed, they cannot control the continued evolution of heat from the steam still in the coils. Further, because thermostats do not respond instantaneously to changes in temperature, kiln temperatures will carry over or under the "set," or desired, temperatures. The amount of carry-over or carry-under will depend upon the steam pressure, amount of radiation, and location of the thermostat or controlling bulb.

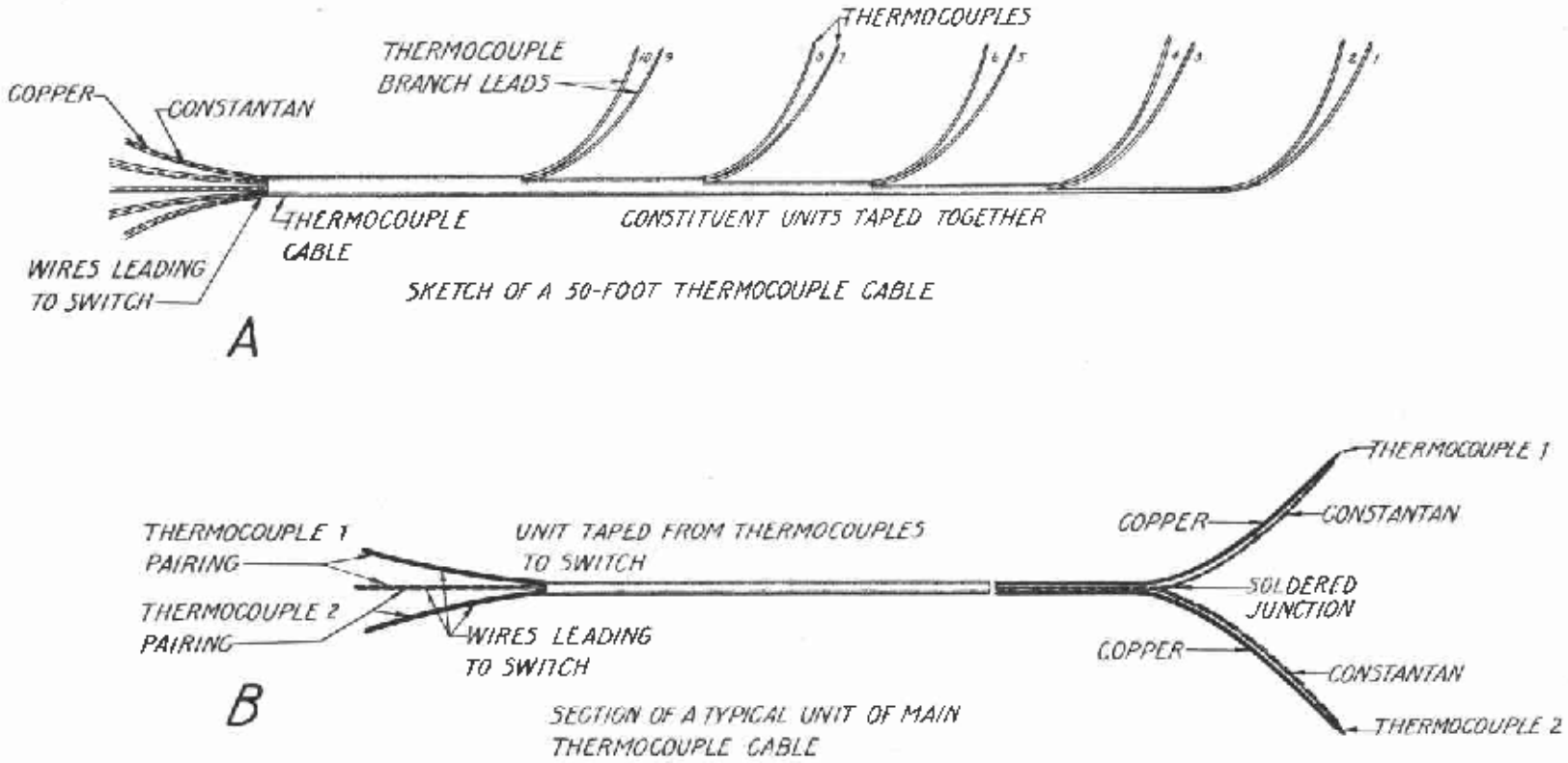
The difference between the low and high temperatures at any station represents a temperature cycle. The greater the cycle, the greater the changes in drying conditions at any one point within the kiln.

Generally speaking, if the thermostat is properly located and functioning correctly, if steam pressures are held constant, and if the proper amount of radiation is used, the temperature cycle will be small, thereby insuring more nearly uniform drying conditions.

Methods of Determining Kiln Temperature Cycles

There are two comparatively simple ways of determining the temperature cycles in a dry kiln, namely, with an indicating thermometer and with a thermocouple setup. If a thermometer is used, it means that the kiln operator must remain in the kiln under actual operating conditions for at least 15 or 20 minutes. This is not only uncomfortable, but dangerous, and is not recommended for all temperatures and relative humidities. The use of a thermocouple, however, enables the operator to record the necessary data while working outside the kiln. Readings should be taken over a period of at least 20 minutes to be sure of a complete cyclic operation.

The cyclic action of the automatic controlling devices must be taken into consideration in setting the thermostatic controller. If the cycle is excessively large (a difference of 5° F. or more), the thermostatic controller should be underset several degrees in order to protect refractory material from possible damage by excessive temperature conditions.



Z K 50455 F

Figure 1.--Thermocouple cable and cable unit.

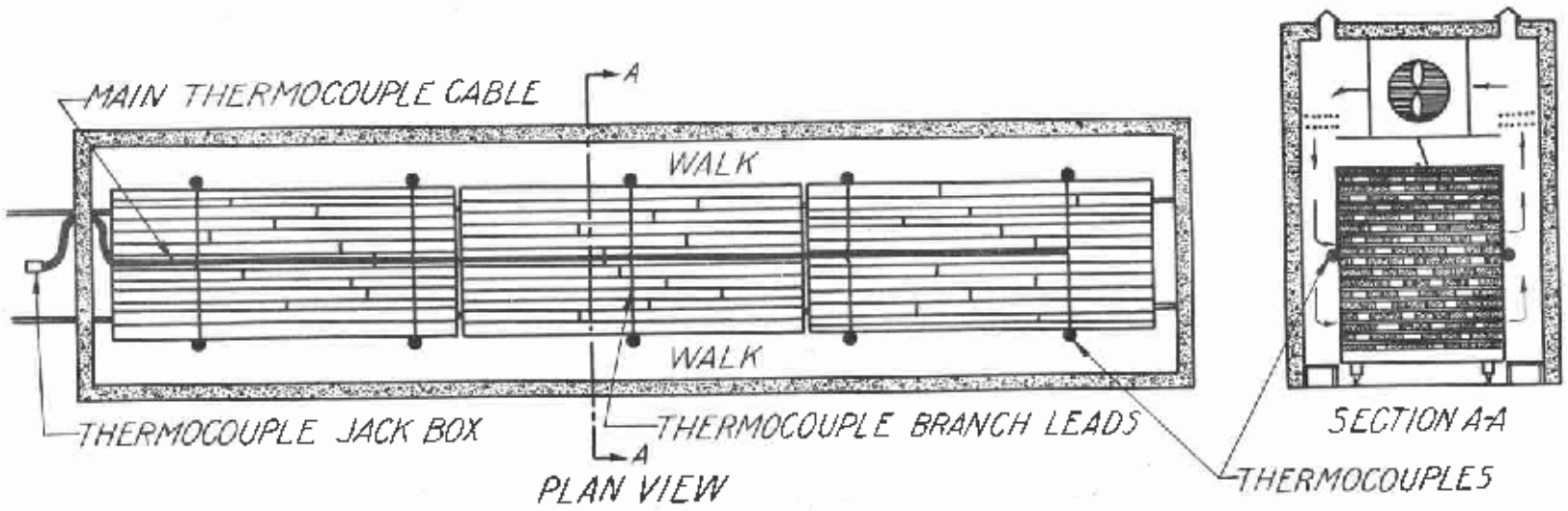


Figure 2.--Suggested method of wiring a single-track, end-piled, reversible-circulation kiln.

Z 3 80128 F

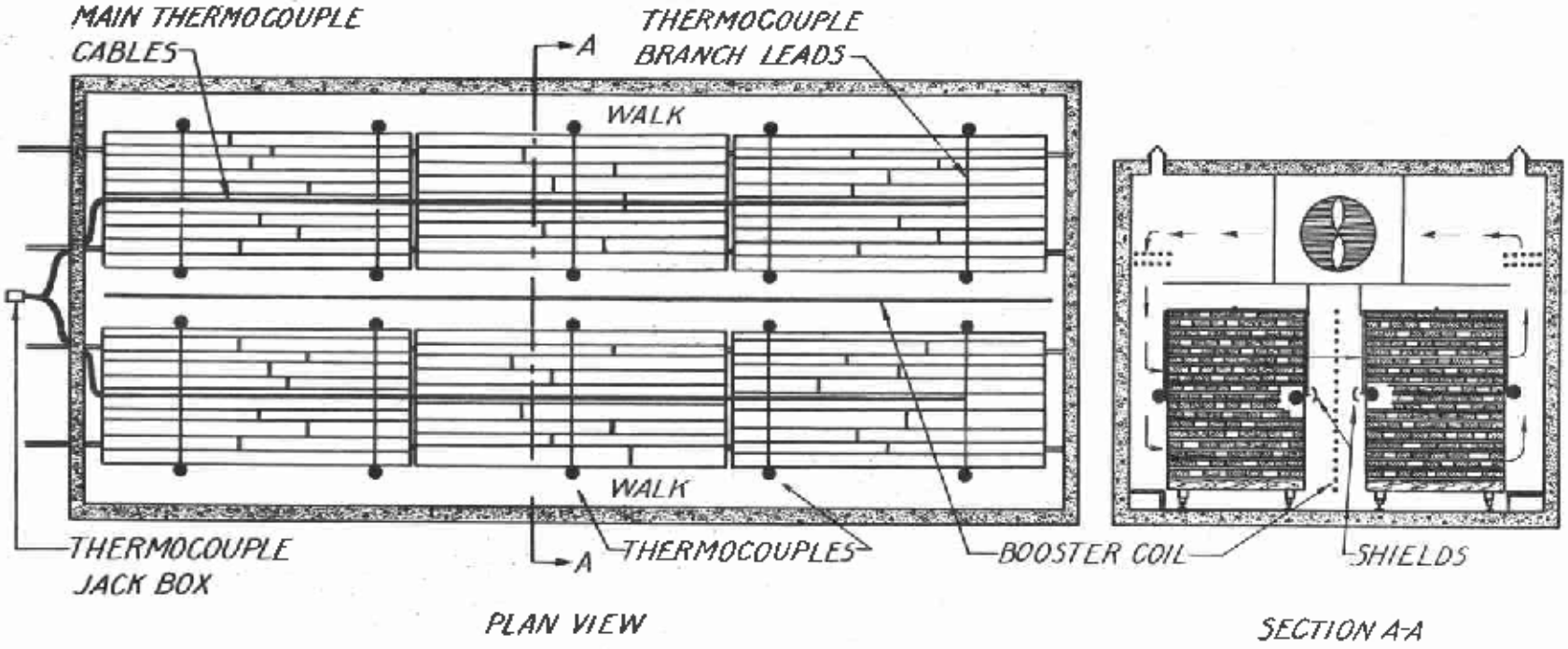


Figure 3.--Suggested method of wiring a double-track, end-piled, reversible-circulation kiln with a booster coil.

2 W 60079 F

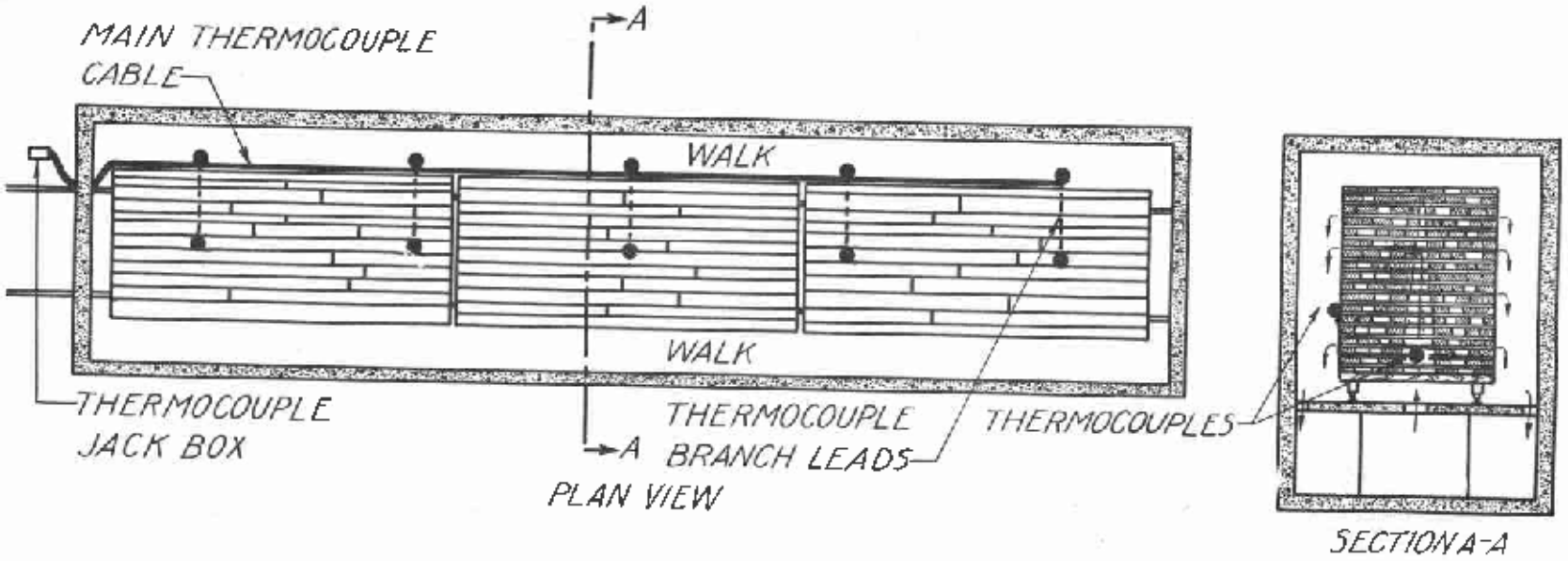
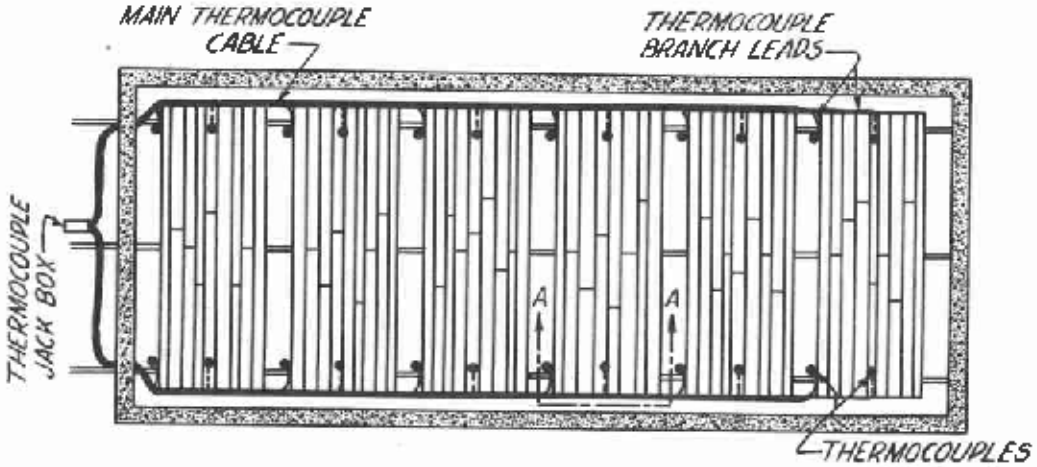


Figure 4.--Suggested method of wiring a single-track, external-blower kiln with an end-piled "A"-flue charge.

Z M 60078 F



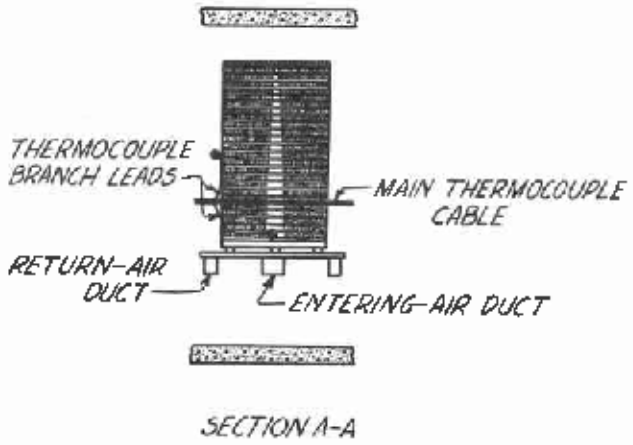
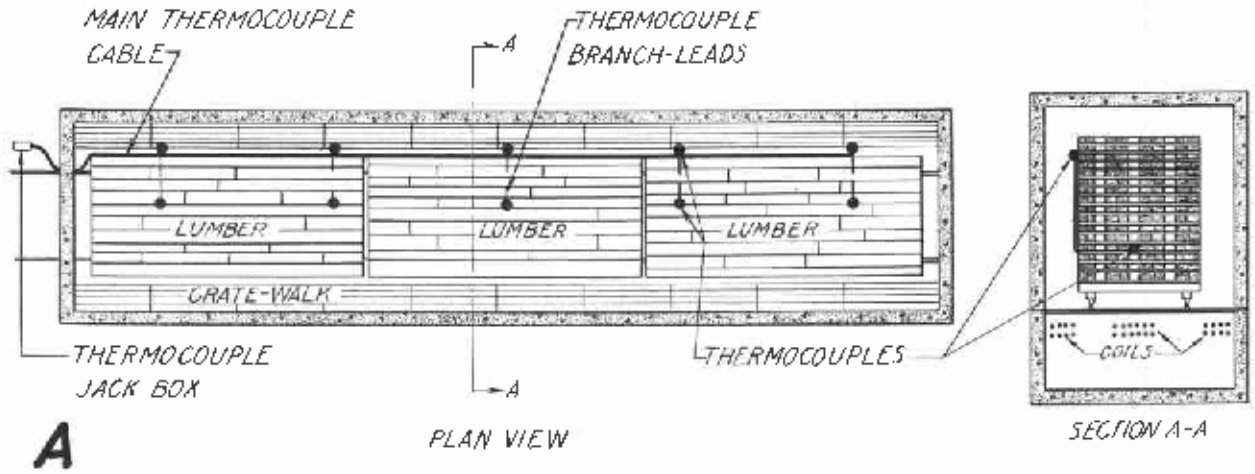


Figure 5.--Suggested method of wiring a transverse-duct, external-blower kiln with a cross-piled "A" flue load.

2 M 60736 F



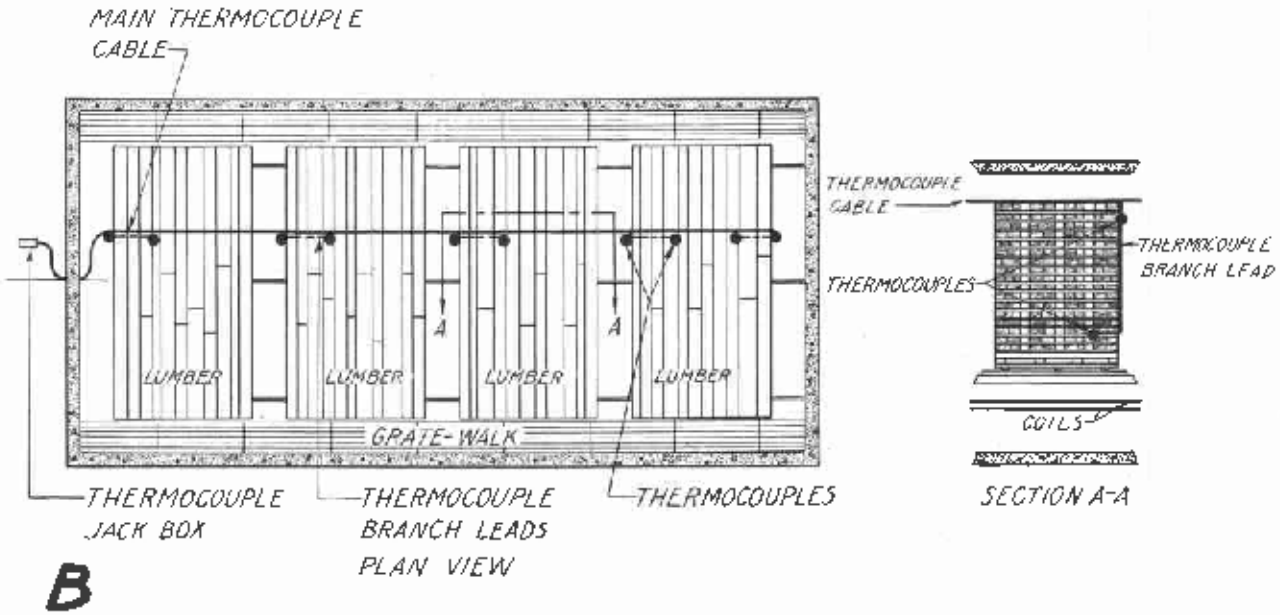


Figure 6.--Suggested method of wiring a natural-circulation kiln.

Z K 59498 F

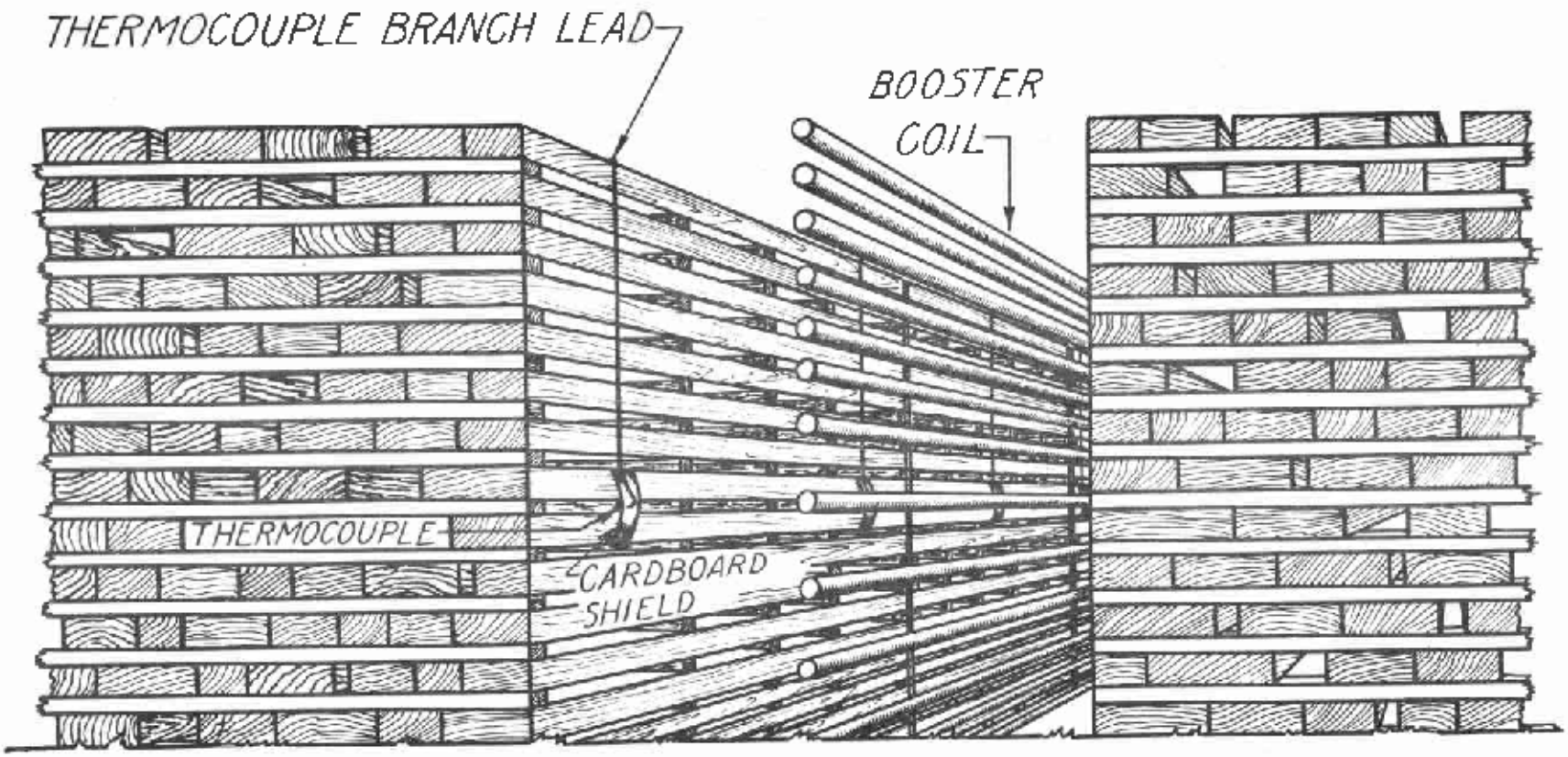
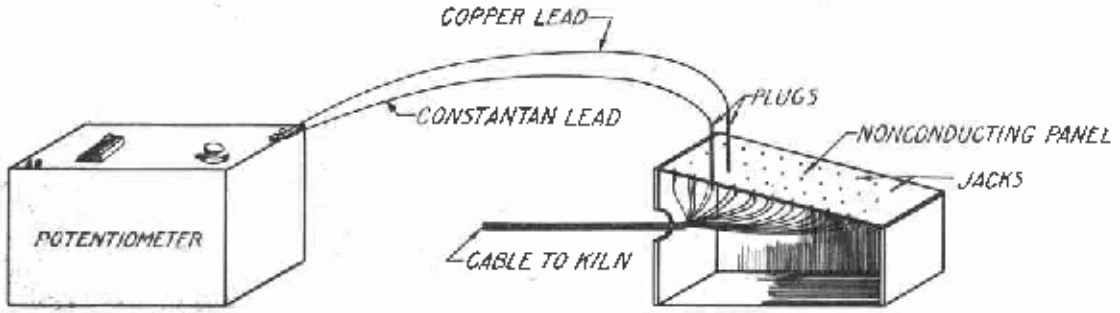


Figure 7.--Portion of kiln charge showing thermocouples shielded from direct radiation.

Z M 60135 F



METHOD OF USING A THERMOCOUPLE JACK BOX AND PLUGS AS A SWITCH IN TAKING THERMOCOUPLE READINGS IN A DRY KILN.

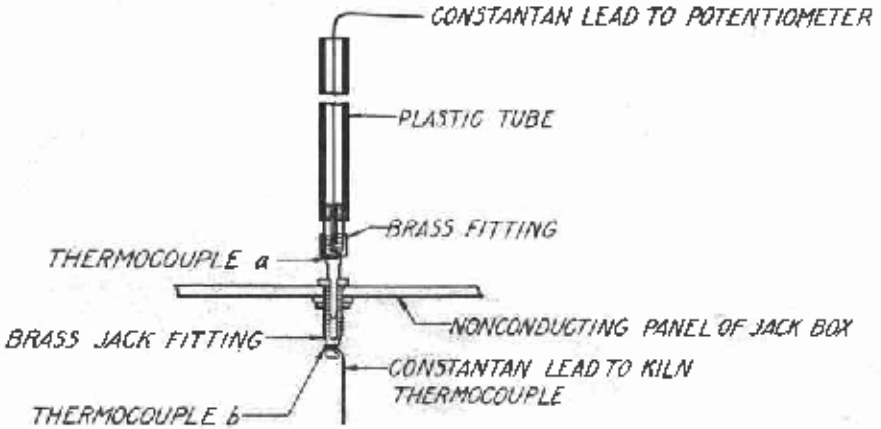


Figure 8.--Section of jack and plug to show thermocouples induced into system at jack box.

SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

List of publications on Box and Crate Construction and Packaging Data

List of publications on Chemistry of Wood and Derived Products

List of publications on Fungus Defects in Forest Products and Decay in Trees

List of publications on Glue, Glued Products and Veneer

List of publications on Growth, Structure, and Identification of Wood

List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products

Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

List of publications on Fire Protection

List of publications on Logging, Milling, and Utilization of Timber Products

List of publications on Pulp and Paper

List of publications on Seasoning of Wood

List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components

List of publications on Wood Finishing

List of publications on Wood Preservation

Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.