

# Furnace-Type Lumber Dry Kilns

## History

A lumber dry kiln is usually thought of as a place where lumber can be dried more thoroughly and faster than by air-drying. The air in it must be heated continuously to replace the heat used to evaporate moisture removed from lumber. The elevated temperatures of a kiln increase the rate of moisture diffusion outward through the wood and stimulate ventilation and air circulation. If the temperature is too high, however, the relative humidity may be lowered to the point where the lumber checks excessively and such refractory species as oak may become honeycombed. "Hot boxes," or kilns without control of temperature and relative humidity, have their limitations and may be found to be cheap only with respect to their initial cost.

A furnace-type lumber dry kiln can be defined as one in which the lumber is heated by the products of combustion, either directly by the gases themselves or indirectly through some form of radiation, such as pipes or the conventional hot-air furnace. In other words, it might be called a boilerless kiln, or one in which steam is not used as a medium of heat exchange.

The crudest type used is the smoke kiln (Figure 1), in which there is no control of temperature, relative humidity, or uniformity of drying conditions. Convection currents carry the hot gases up through the lumber pile from an enclosed fire pit below. This type is often called the "Arkansas kiln" and is still used at a few small Arkansas mills to dry Southern yellow pine. Better results with less fire hazard are obtainable where the fire and hot gases are confined within regular combustion chambers and flue pipes.

C. J. Telford, small-sawmill specialist at the Forest Products Laboratory, developed a design for easily dried species that is an improvement over the smoke kiln but is not entirely satisfactory with respect to the fire hazard as well as the drying rate and the uniformity of final mois-

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ture content of the lumber (7).<sup>1</sup> An improved design of the natural-circulation type, which dries wood faster, has the heating pipes in a deep pit below the loads, as in conventional steam kilns of the natural circulation type; and a safer and more permanent structure would be of brick, tile, or cement blocks.

The European Bachrich kiln (1) has a furnace room located between drying chambers. Sawdust, chips, and other forms of wood waste are burned in the furnace, and the flue gases pass through fire brick and steel flues located below the loads. Originally, this type was constructed as a natural-circulation kiln and some, possibly, are still built that way. Internal fans, however, are now recommended for better air circulation through the load. A small steam boiler can be connected to the furnace to provide steam for humidification when needed. It is believed that this humidifying system is particularly desirable for fan installations.

Another furnace-type lumber dry kiln was developed at the British Forest Products Research Laboratories, Princes Risborough, England (6). It is a sawdust-burning, internal-fan kiln. The results were generally satisfactory in drying two-inch Douglas fir, one-inch oak, and three-inch Scots pine. Some trouble was experienced with humidity control.

Other furnace-kiln designers and builders have also adopted some form of fan system similar to those used in modern steam kilns. The Forest Research Institute, Dehra Dun, India, has designed and operated indirect-heated, internal-fan, furnace-type kilns for drying packing-case timbers. The following conclusions are quoted from a bulletin (5) on this kiln:

"1. The blower-cum-furnace kiln for the rapid drying of packing-case

timbers is efficient in operation and gives satisfactory results with the seasoning of light non-refractory hardwoods.

"2. The time required for the seasoning of semul and bhelu planks was found to be the same as that taken for drying these timbers in a steam-heated kiln.

"3. The quality of the seasoned material was good. The timber was almost free from all forms of seasoning de-grade at the end of the drying period.

"4. The initial outlay of capital is reduced appreciably as no boiler is required for a kiln of this type. Running expenses are also reduced too because no trained boiler staff is required.

"5. No tests have been carried out on the seasoning of ordinary hardwoods in this kiln, but most probably it will not be suitable for the drying of refractory timbers, for which proper control over the temperature and the humidity of the air circulating in the chamber is essential."

The Seasoning Section of the Division of Forest Products, Australian Council for Scientific and Industrial Research, South Melbourne, proposed a design (2) the principle of which is that of the over-head, internal-fan, cross-shaft kiln, with six-inch wrought iron pipe substituted for the usual smaller-diameter steam pipe. The idea was to use a chimney stack near an outside furnace or incinerator until the fire is going properly, then to close this stack and use a second one located on the opposite end of the kiln, so that the draft from this stack would draw the flue gases through the heating pipes. By using dampers, some degree of heat control could be obtained. Although this design had not been tested up to December, 1942, it was expected to prove satisfactory for container lumber or other material of this nature.

Before World War II, fire hazards and poor control of drying conditions had discouraged the general use of furnace-type kilns, and most American

<sup>1</sup>Number in parentheses refer to literature cited at end of this report.

kiln companies and engineers felt justified in confining themselves to steam kilns, in which control and distribution of heat and humidity are simplified by the use of steam radiation and steam spray lines. The shortage of dry lumber, and kiln equipment as well, during and following World War II, however, stimulated the development of several designs, some equipped with sawdust burners and some with oil or gas burners. As there is a definite need for such kilns, particularly at small plants where steam is not available for kiln use, the Forest Products Laboratory has encouraged this development by doing some design work in this field. The greatest amount of work has been done on a kiln of the internal-fan type using a commercial sawdust burner for heat, and vent control and water sprays for humidification.

### Forest Products Laboratory Design

An experimental furnace-type unit (Figures 3 and 4) was built on the Laboratory grounds and operated for about one year (8). The structure is of wood both inside and outside, and is insulated with dry sawdust. Its outside dimensions are 18 by 25 feet divided into a 7- by 18-foot furnace room and an 18- by 18-foot drying compartment. This size provides space for a heating pipe on one side and a pile of lumber 8 feet wide, 10 feet high, and 16 feet long on the other. Its capacity is approximately 7,500 board feet of full-length, one-inch lumber piled on one-inch stickers, or correspondingly less if the lumber is random-length and box-piled.

The heating plant consists of a commercial sawdust burner having about 4 square feet of grate area, a secondary combustion chamber, and a multiple-return bend type of combined smoke pipe and radiating surface. Air circulation through the load is provided by two 36-inch fans direct-connected to 1½-horsepower motors. The cost of construction (1944) was about \$3,000. The drying of 4/4-inch green pine, maple, and even oak in this unit proved satisfactory both as to drying time and drying degrade.

A similar unit was built by a lumber producer at Grand Marais, Minn., in cooperation with the Forest Products Laboratory and put into operation during June, 1946. The kiln was wanted to supply kiln-dried pine for the firm's planing mill and is performing satisfactorily. Instead of individual motor-fan units, two 48-inch disk fans are mounted overhead on individual shafts that extend through the side walls to the outside, where each is connected to a one horsepower motor by means of

twin V-belts. One fire has resulted from an attempt to use dry sawdust and shavings from their planing mill in their sawdust burner. For this purpose a screw feed had been installed which, when not operating, allowed the fire to work back into the fuel storage bin.

A commercial kiln having a capacity four times that of the Laboratory unit was constructed by a Wausau, Wis., firm at Merrill, Wis., in cooperation with the War Production Board and the Forest Products Laboratory. This kiln was put into operation during February, 1945, and has been in continuous operation, except during three reconstruction periods when fires destroyed certain portions of the roof, sawdust storage bin, and furnace room. These fires also were due, at least in part, to the use of dry sawdust and shavings from a planing mill. This dry material was used because the sawdust was stored outdoors and was often too old and soggy to burn satisfactorily. The dry shavings, on the other hand, burned too vigorously in the burner and back into the hopper and did not feed properly through the hopper. As the sawmill is operated only part time, there is not a continuous supply of fresh sawdust. Consequently, it was decided to eliminate this trouble by replacing the sawdust burner with an industrial-type oil burner. Large amounts of northern Wisconsin hardwoods and softwoods have been dried from both the green and air-dried con-

dition, and the drying results have been good with either sawdust or oil for fuel.

The original cost of this unit was approximately \$9,000, which can be roughly subdivided as follows: \$3,000 for building, \$3,000 for the heating and humidifying system, \$1,500 for motor-fan units and baffles, and \$1,500 for track, trucks, and laboratory equipment, such as small weighing scales, an electric oven, and a band saw. Most of the work was done by the regular mill crew, which was inexperienced in the construction of lumber dry kilns. This fact, plus some extremely cold winter weather, probably increased labor costs for the building and the installation of equipment.

A low-temperature, wind-tunnel type of lumber dryer has been developed on the West Coast in which hot-air furnace heat can be used as well as steam heat (4). It was developed by the West Coast Lumbermen's Association.

### Commercial Gas- and Oil-fired Kilns

In Arkansas and some neighboring states, natural gas is relatively cheap and generally available. As a result, kiln engineers in that region have designed gas-fired furnace-type kilns to satisfy the increased demand for kiln-drying facilities at many small plants operating with power other than steam (3). The cost and shortage of modern steam-kiln equipment have also prompted designers to use cheap and

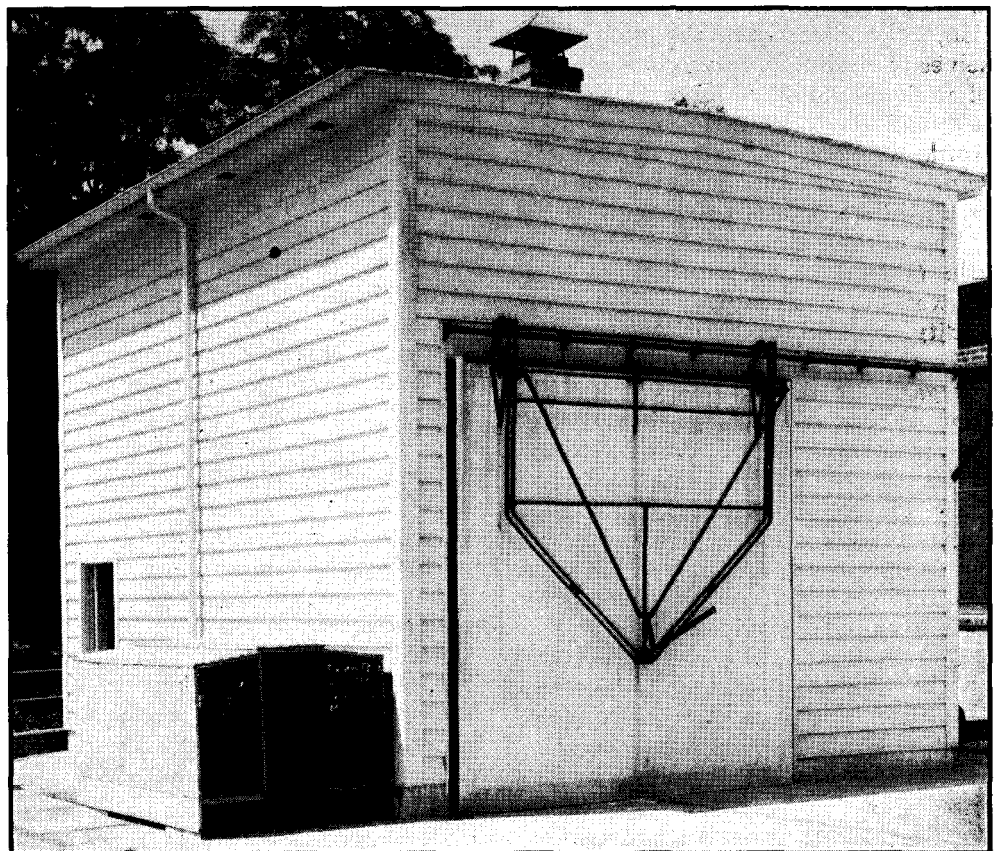


FIGURE 3.—The experimental furnace-type kiln built on the grounds of the Forest Products Laboratory.

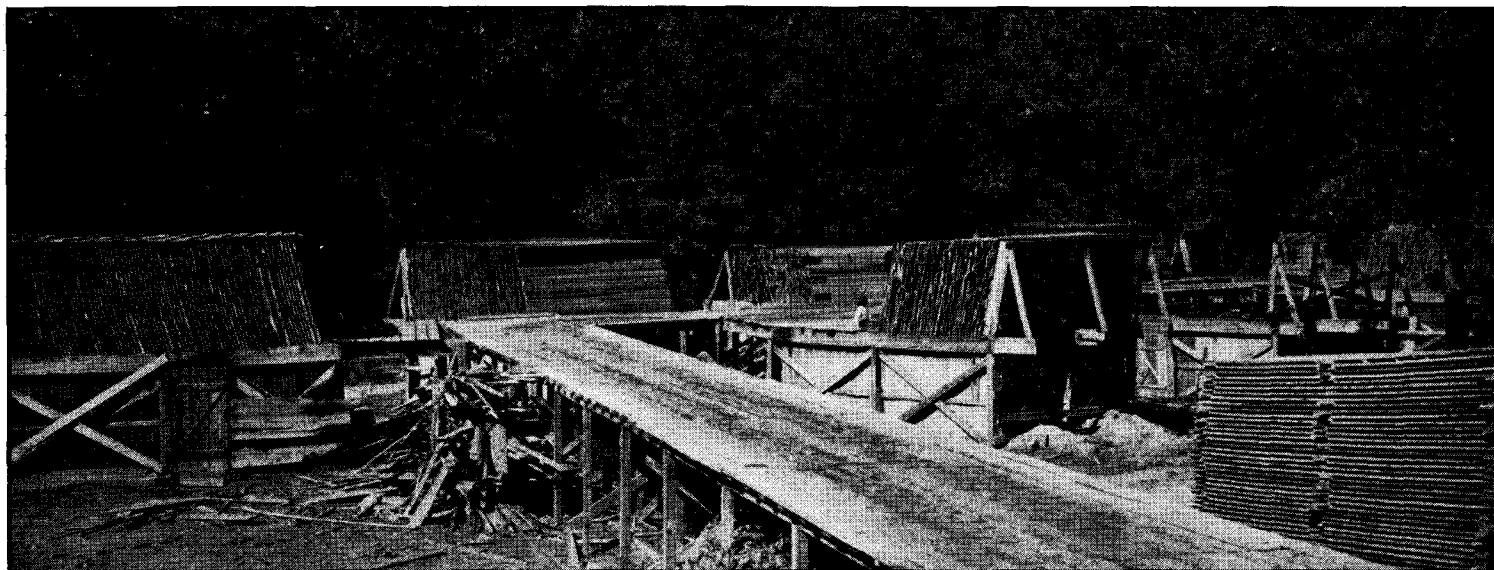


FIGURE 1.—One type of smoke kiln used in Arkansas. In some cases, the lumber platform as enclosed on two sides and covered by a fixed roof. A slow fire of slabs and edgings is maintained within the enclosure below the lumber.

available materials, such as second-hand sheet iron pipes.

In one design of gas-fired kiln, a natural-circulation type, longitudinal flue pipes and connecting laterals extend throughout the area below the tracks and lead from a tunnel-shaped fire-brick combustion chamber into an outside stack. Apparently, the use of second-hand pipes has made possible the building of a rather large number of these kilns without extended delays, and as a result facilities for kiln-drying green pine and air-dried hardwoods have been appreciably increased in that area.

In several designs, internal fans are used to recirculate the air through the lumber piles, and the products of combustion go directly into the kiln. In one of these, heat is furnished by a series of small individual burners extending lengthwise down the center area between tracks. They are enclosed within a sloping metal shield, which has openings in the top to permit the hot gases to escape into the area directly below the recirculating fans. The burners at each end and in the center have separate supply lines, so that they can be regulated from the outside to produce the required temperature uniformly throughout the length of the kiln.

In another design using internal fans, the furnace is located outside the kiln and the hot flue gases pass into a metal pipe that extends longitudinally down the center space. The gases then pass into the kiln through small openings spaced at intervals along the top side of the pipe. In still another design, the heat is supplied by a gas furnace at each end of the kiln and passes into large metal heating ducts that extend towards each other to the center of the kiln between the tracks.

A major manufacturer of steam dry

kilns has also entered this field, using the same longitudinal shaft and internal fan arrangement used in its steam kiln. In this design, however, the products of combustion are carried outside within the radiating metal flue pipes.

Another concern that has plans and equipment for an external gas-fired furnace-type kiln uses an external fan to circulate the heated air through distribution ducts into the kiln and then back through the furnace and fan.

Oil-burning as well as gas-burning equipment is in use, and one firm with considerable experience in the design and construction of tobacco driers using an oil-burning furnace and an external blower for air circulation has recently worked out a special design for lumber drying.

The general picture with respect to these kilns is that they are still in the development stage, with changes being made to reduce the fire hazard and to improve control of temperature and relative humidity. Fires have been sufficiently frequent to make insurance companies skeptical as to the advisability of insuring furnace-type kilns at acceptable rates. This situation is, at least in part, due to operating methods. Great emphasis has been placed on short drying periods, to achieve which extremely high temperatures are commonly used, particularly towards the end of the drying process when some of the lumber may have become excessively dry, thus increasing fire hazards. Lack of good control of drying conditions has also been due partly to this use of high temperatures, which increase the difficulty of maintaining desirable humidity conditions, especially towards the end of the run when relatively little water is being evaporated from the lumber. Water

sprays, or steam sprays from a small, low-pressure auxiliary plant, must be installed and then used properly to provide sufficient humidification at the end of the run to equalize moisture content and to relieve case-hardening stresses.

With some lumber items, however, relief of stresses is not considered essential. This is the case with lumber used for general construction purposes, or for other uses where resawing and shaping are not required. In drying oak flooring, there is some doubt as to the necessity of relieving stresses, but there is no doubt as to the need for a uniform moisture content of about five to seven per cent when the lumber is taken out of the kiln and run into flooring. In other words, these gas kilns have been satisfactory to the owners in drying green pine and air-dried oak for flooring, but some trouble with checking and honeycombing in oak has occurred when the oak was not sufficiently air-dried before going into the kiln. Some uses of oak, however, require freedom from checks and case-hardening stresses, and in such cases particularly, the present run of gas-fired kilns should be improved both as to control equipment and operation. Such improvements are gradually coming into use.

### Summary

Among the major causes of, and remedies for, the faults that have hindered the development of an efficient and satisfactory furnace-type kiln are the following:

1. In the past, many kilns of this type were built cheaply by persons inexperienced in this field. This often resulted in poorly dried lumber and in destruction by fire after only a short period of operation. The remedy is better designs by experienced persons,

such as heating and ventilating engineers. More consideration should be given to efficient design and operation than to cheapness in initial cost in order to secure better-dried lumber and curtail drying losses.

2. The fire hazard can be greatly reduced by care in design and construction, and particularly by care in operation. Furnaces of all kinds are used in homes and industrial plants without trouble when installed and operated properly, and there is no reason why they cannot be used safely to heat a kiln. Additional protection from fire losses can be provided by the

installation of fire lines of the automatic sprinkling type and by keeping the kiln clean and free from excessively dry debris, especially around the heating surfaces.

Using the wrong fuel or firing the furnace beyond its normal capacity must be avoided. For instance, a sawdust burner and its hopper will remain relatively cool when burning green or only partly dry sawdust. A satisfactory fire is maintained practically automatically by gravity feed of fairly green sawdust in the hopper, and temperature control is good between rather wide limits. Dry sawdust and

shavings from a planing mill, however, should not be used in such burners because they do not feed properly and burn too vigorously, causing a red-hot pipe next to the combustion chamber and extremely high adjacent temperatures within the kiln.

3. Temperature control within limits desired in a lumber dry kiln is difficult in any furnace where the fuel is fed in by hand, even though a thermostat is used. The use of gas, oil, or a coal stoker simplifies this difficulty to a large extent, and even the sawdust burner with its automatic feed of sawdust from the hopper was found to give

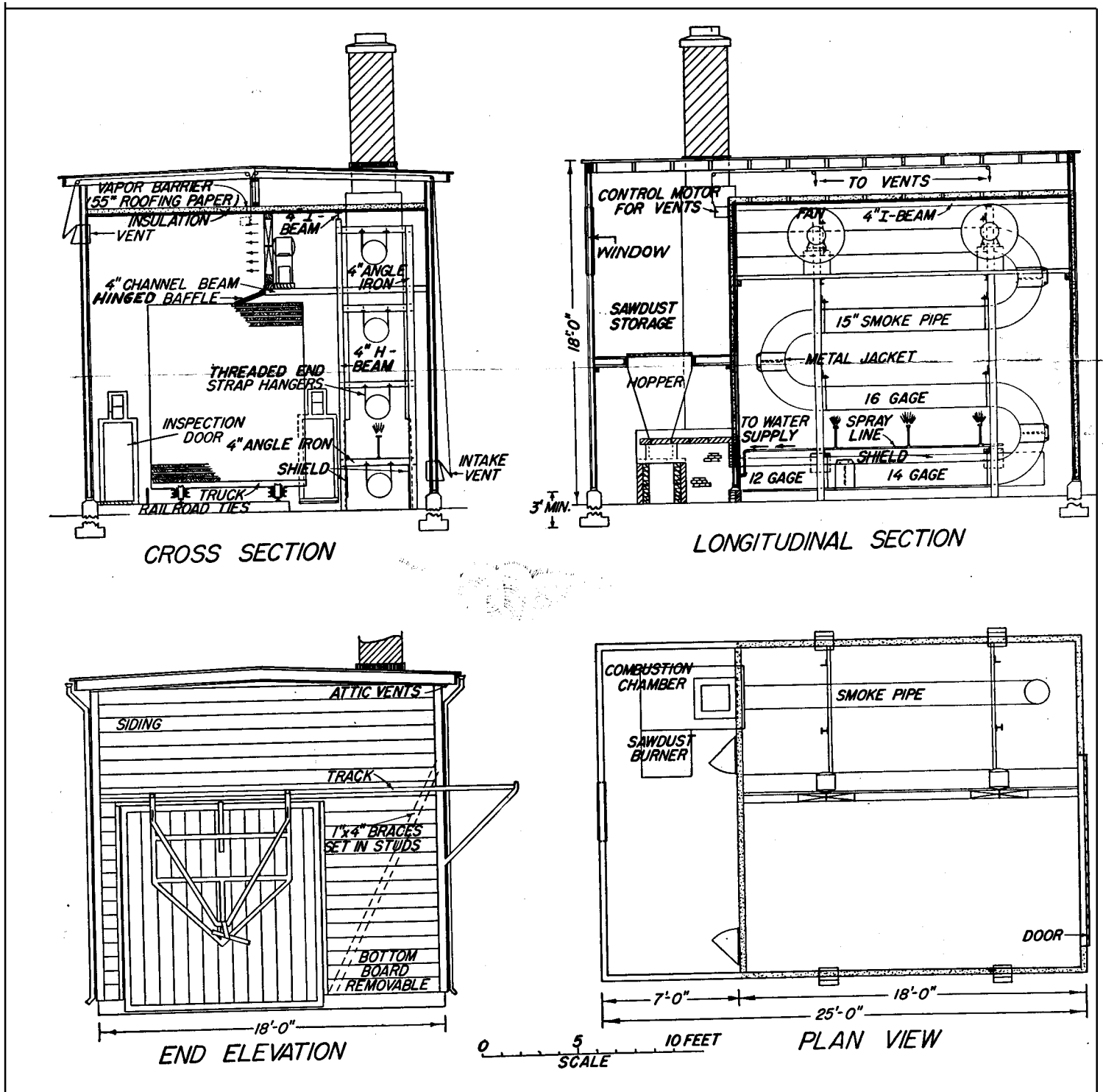


FIGURE 4. —Some of the details of construction in the Forest Products Laboratory's furnace-type kiln of one-truck capacity, similar to the units built at the Laboratory and at Grand Marais, Minn.

much better control of definite kiln temperatures than a hand-fired coal-burning furnace using the same type of thermostat for control. Without good temperature control, it is particularly helpful to use some form of hygostat to operate the vent dampers and the water or steam sprays. The wood-element hygostat tends to maintain a fixed equilibrium moisture content condition which, for all practical purposes, is equivalent, within limits, to maintaining a fixed differential between the wet-bulb and the dry-bulb temperatures.

4. As water sprays are not so convenient and effective as steam sprays in controlling the relative humidity, it is particularly important that furnace-type kilns be constructed with a good vapor barrier and well-fitting doors, so that full advantage can be taken of the evaporated moisture for humidity control through the use of tight lids or dampers on the vent ducts. These lids or dampers can be operated satisfactorily either by hand or automatically by the wood-element hygostat. For fast- and easy-drying green stock, the vents must be adequate in size to maintain a satisfactory drying rate. In some cases, a vent area of 20 to 30 square inches for each 1,000 board of feet of green lumber may be required while, on the other hand, air-dried lumber is often dried in kilns without vents, leakage through the structure and doors being sufficient. It would be better to

have a tighter kiln with vents properly distributed, although without tight lids or dampers, too many vents may be a detriment because of excessive leakage.

The vent area requirement is influenced a great deal by the kiln temperature and for that reason the desired humidity condition can be attained by temperature adjustment in case vent and water spray operation do not produce the results desired. This was demonstrated to a limited extent in operating the Laboratory's furnace-type kiln, by using the wood-element hygostat to control the draft door on the sawdust burner. Such a drying schedule might be called an equilibrium moisture content schedule. Disadvantages would be that the resulting temperatures may be lower than necessary for some species from a drying-time standpoint or possibly too high for some items such as oak of high moisture content. As a safeguard, a thermostat in the drying compartment and possibly a limit switch in or near the furnace should be provided.

5. The design and construction of a furnace-type kiln require care as well as some knowledge of building construction and the factors involved in any drying operation. Fully as important, however, is knowledge of the proper technique in drying lumber, along with some common sense in applying that knowledge. Too much

emphasis on cheapness in construction and operation, and unusually short drying times by the use of high temperatures, are often the causes of fires and poorly dried stock. When proper consideration is given to these factors, there is no reason why furnace-type kilns of one form or another should not serve successfully at the many small mills and wood-working shops or plants where the use of steam would be especially inconvenient and expensive, and where the location is favorable for securing suitable materials and services.

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