CONSTRUCTION AND INSULATION
OF DRY KIISNS

Form of paper good. Considering technical character of the paper, it was well presented in class. Detail of chart, good.

Grade 7.

Submitted by: John D. Moffett
Feb 29, 1932
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PREFA3E

In writing this paper, it has been my intention to present in a brief and non technical discussion certain fundamentals necessary to a complete understanding of construction of dry kilns to secure a maximum of insulation.

Although there have been great advances made in insulation in the past few years the fundamentals of the problem will never change.

Lumber is kiln dried not only to secure underweights, but to improve the quality. Due to the developments of the last three years, it is vitally important that drying be accomplished as economically as possible.

If by a thorough understanding of the principles involved in insulation a more efficient operation has resulted the industry has profited.

April, 1932.

John Miffitt.
INSULATION AND CONSTRUCTION OF DRY KILNS

In the construction plans for a building of this type, insulation is the key note to all construction details. Very little attention has been paid to this factor in the past, and as a result kiln buildings are failing to meet the rigid requirements which new methods and equipment exact.

Although insulation is the key factor in kiln building, other important details must not be overlooked. Any type of building to be considered must be adapted to the size and permanence of the operation. In other words, the building must be practical. A wise lumberman will endeavor to determine just how large a kiln he will need, the cost, the length of time it is to be used, relative advantages of certain types, and in making a choice, choose a kiln which satisfies these conditions.

Kiln buildings in addition to being affected by ordinary weathering conditions on the exterior, are subjected to high temperatures and humidities on the interior. This alternate expansion and contraction of the construction materials is facilitated further by the working of lumber which is used in construction. This working is caused by changes in moisture content of the pieces.

Certain types of steel cannot be used for track supports, pipe coils, and other necessary kiln equipment since the corrosive effect of acid vapors quickly destroys such steel.
When high humidities are used many of the ordinary insulating materials which have not been properly protected from moisture become saturated, thereby materially lowering the insulation values.

Circulation of air maintained in the kiln also plays an important part in the selection of a kiln building. The higher the velocity of air circulation maintained, the tighter the construction must be, since the air pressure inside tends to force the air out to regions of lower pressure.

Hence in the final analysis of a building material for kiln construction, it must be strong, durable, resistant to corrosive acids and vapors, reasonably tight, adaptable to construction, impervious to water vapor, a reasonably good insulator, and lastly, be capable of installation at a low cost. However, the real cost of the material should not be quoted in so many dollars and cents per square foot of surface, but should be quoted as so much per unit of insulation secured.

In determining specific construction means and materials it is necessary to go deeper into the subject of insulation. Heat is transferred by three methods: conduction, convection, and radiation. Any one of these factors may operate separately or any combination may occur.

Conduction of heat may best be illustrated by placing one end of an iron bar on some heating element and observing how the heat is transferred along the bar. The ability of different materials to conduct heat varies greatly and is perhaps best in
metallic substances.

Radiation of heat is commonly observed while standing in front of an open fire. This heat transfer is independent of the presence of air as may be observed by the radiation of the sun's energy thru space which is devoid of matter.

Convection is transfer of heat brought about by movement or currents of fluid or air. Motion may be gained mechanically as by blowers and fans or automatically by means of variations in temperatures.

Recent tests made by the Forest Products Laboratory indicate that heat losses due to radiation are much more important than formerly believed. Their tests indicate that about one half of the heat transfer thru building walls may be ascribed to radiation. As a rough approximation, losses of heat by convection are in direct proportion to the differences in temperature between the two faces.

Measurements of conduction are more difficult, as the exact nature of the process is not completely understood. The thermal conductivity of any given material is measured numerically in terms of British Thermal Units. One B. t. u. may be defined as the amount of heat necessary to raise one pound of water one degree Fahrenheit. The standard calculations of thermal conductivity are based upon the number or fraction of B. t. u. that will flow in one hour thru a uniform layer of material one square foot in area and one inch thick, when the temperature difference between the two faces is one degree Fahrenheit. The insulating value or thermal resistivity of a material is equal
to the reciprocal of the thermal conductivity for 1" material, or the thickness in inches divided by the thermal conductivity for thicknesses other than one inch.

Thermal conductivity is a property of the material itself, and is not dependent upon the size or shape of the material, providing the piece is of uniform construction. It is then, incorrect to speak of the thermal conductivity of a wall or structure, as the term "thermal conductivity" refers to the material or materials of which the wall or structure is composed.

When dealing with a structure or wall, the insulating value is measured inversely by a property known as the conductance. Conductance may be defined as the number of B. t. u. flowing thru the wall in unit time and unit area when the temperature difference between the two faces is one degree Fahrenheit. If the composition of a given wall is uniform, the conductance, expressed algebraically, equals the conductivity of the material divided by the thickness of the wall. If the material is heterogeneous conductance equals one divided by the insulating value. Working backward, the insulating value or thermal resistance equals the reciprocal of the conductance.

When the temperature difference between the two faces of a wall are constant the steady flow of heat thru the wall depends on four partially independent processes: (1) the transfer of heat to the wall from the surroundings on the hot side, (2) the transfer thru the wall, (3) the transfer of heat to the
surroundings on the cold side, and (4) the diffusion or flow of air through the wall in either direction.

Resistance to heat flow between the surface of a wall and its surroundings is ordinarily called surface resistance, although only partially dependent on what takes place at the surface of the wall. Heat in this case is transferred to the wall by convective currents set up either by mechanical or automatic means. At points very near the wall, velocity of the air is checked and motion becomes approximately parallel to the wall surface. As the velocity of air is increased the parallel motion of the air becomes closer to the wall. From the point where the parallel, rapid moving convective currents cease and the solid face of the wall begins the heat is transferred mainly by pure conduction through the slowly moving layers of air. Hence, any direct increase in air velocity decreases the surface resistance.

In addition to transfer of heat by convection and conduction transfer between the surface of the wall and its surroundings also takes place by radiation. The magnitude of such transfer, depending directly on the absolute temperature and the temperature difference, is very great.

The thermal resistance of the wall is a property of the wall and is not influenced by surroundings except in cases of air leakage. Heat transfer through solid wall takes place only by conduction, and in direction of the temperature gradients. This transfer is proportional to the temperature
difference between the two surfaces, and also depends on the material in the wall.

Aside from the three basic methods of heat transfer, an entirely independent transfer of heat may take place by infiltration of cold air through the wall on the windward side of the building, with a consequent forcing out of warm air on the lee side. It is evident that an impermeable layer at one place in the wall will entirely eliminate air infiltration to the interior, but not necessarily annul the effects of partial air penetration on the total heat loss thru the wall.

When the temperature on the two faces of a wall varies from time to time, certain important factors enter into the problem of heat flow through a wall. As the air temperature and external wall surface temperature fall rapidly during the night, heat flows outward from the wall at a greater rate than it flows into the wall from the inside. The flow of heat into the outside air is maintained at the expense of heat stored in the wall, and it is only when this store is exhausted that a steady flow is again secured. If a wall is very thick, that portion of wall near the inside of the building is still losing heat at the same rate the next morning when the outside temperatures rise. This tends to a storing up of heat by the outside layers, consequently, the net heat losses remain unaffected from day to day.

Looking at the construction of a suitable dry kiln from the standpoint of insulation alone, the most important factor that must be considered is the thickness of the insulation to be
applied. At present no known material in a thin layer will provide sufficient insulation for a building of this nature. On the other hand a very thick layer of material may not be economical, since little percentage increase in insulating value is secured by increasing the thickness.

A good insulator is essentially a material having a large percentage of relatively small voids containing air. This prevents any appreciable amount of convection taking place, and the solid portions effectively screen off the radiation, thus utilizing to a great extent the low conductivity of air space. Since every known solid material has a greater thermal conductivity than air, it is evident that the conductivity of air fixes the lower limit of the conductivity of insulating materials containing air.

If a layer of average insulating material is placed in the middle of a wide air space, as between the studs in a frame building the resulting insulating value is greater than if the material was placed in contact with the sheathing. The explanation of this lies in the fact that the insulating material not only adds its insulating value to the wall, but in addition divides the air space into two parts, each of which has about the same insulating value as originally. However, as pointed out before, the air spaces materially increase the losses of heat from the inside, due primarily to radiation and convection.

Foundations for the walls of the kiln are usually of concrete. The customary practice is to build the concrete up to
track level, even when other materials are used for the upper portions of the walls proper. Where good substantial soil is available the subfootings are not elaborate, but on soft soil large subfootings should be used to avoid the possibility of settling. Foundation walls for wood construction average from 7 to 10 inches. For concrete, brick, or tile construction they usually are from 12 to 14" thick. Four inch concrete floors with provision for drainage are generally considered adequate.

Wood frame buildings are usually constructed of 2 x 6 vertical studs, with two layers of 1" lumber on the inside of the studs with single ply roofing or building paper between the two layers of lumber. The outside of the stud is generally covered with 1" board or siding. This makes a very satisfactory insulated type of building, but carries a rather high fire insurance rate and the construction will not last very long, especially when drying woods employing high humidity schedules, such as Douglas Fir.

Where wooden walls are used, cribbing, studding and sheathing, or studding with various gypsum and diatomaceous fillers may be used. Concrete walls, reinforced with steel, brick, terra-cotta tile, or various combinations of these materials are frequently used with good results in kiln construction. Diatomaceous earth has been used as a filler in various types of construction with a great percentage increase in insulation value.
Some building is done using wood crib or laminated wood walls. Pieces 2 x 6 are laid flat for the walls and either run with a groove and spline, or shallow tongue and groove to get tight construction. This type of building construction gives approximately 5 1/2" of wood, which makes a very well insulated building.

To give good satisfaction the roof must be structurally sound, weatherproof, a good insulator, and nearly flat. Selection of a material to meet these requirements is difficult, but good results have been gained by use of tile, wood, and concrete. A crib construction roof, using pieces 2 x 6 gives better insulating value than the 6" tile and concrete roof. This type of roof is used extensively in the colder sections of Eastern Washington and Montana. In cold sections where a permanent type of concrete construction is used a variety of insulating materials are used to prevent and reduce heat losses, particularly thru the roof.

As the door is the weakest and the most unsatisfactory part of an average kiln, it should require considerable attention. A strong, light, tight, easily handled door, of high insulating properties, capable of resisting corrosive effects of acid vapors is very difficult to secure. These doors are constructed in various ways, some employing wood slab construction—others, 3/4" plywood on angle iron frame, and still others with plywood insulation with metal covering on each side of the insulation. This metal covering is particularly resistant to corrosive acid vapors.
Several firms build kiln doors using cork for insulation. Others use various combinations of asbestos, gypsum, and firtex. Insulated doors should be used in all cases, especially in colder climates where there is a large spread between the outside air temperatures and the operating temperatures in the kiln.
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American Society of Heating and Ventilating Engineers Guide-1930
# MISCELLANEOUS BUILDING MATERIALS

D - Weight in lbs/cu. ft.

K - Thermal conductivity in B.t.u./hr./inch/sq. ft/°F.

HC - Heat conductance in B.t.u./hr./sq. ft/°F.

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Hollow tile—H. C. values

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Note: Conductance of air space 1/2" or more in width is taken to be 1.10 B.t.u./hr./sq. ft./°F.
Dry Kiln Roof
Insulated with Diatomite

Johns-Manville 15-Year Roofing

2" Concrete with 1" Ø Rods 16" @ BOTH WAYS

2" of Tar

TAR PAPER

6" Diatomaceous Aggregate

¼" of 220° Tar

6" Concrete with Ø Rods 6" @ CROSSWISE

5/8" Ø Rods 18" @ LENGTHWISE

Lintel

 STD. No B-26 Moore Dry Kiln Company
 NORTH PORTLAND, OREGO

3-5-30 1/2" = 1'-0"

W.E.B NP. 1597