There has been some confusion in the past regarding the subject of using direct fired heat versus steam as a heat agent in a dry kiln. We must remember that a heat source is just simply that. The heat can be applied inside of a dry kiln for producing energy to evaporate moisture by several sources. This could be by the use of steam heated pipes as in the conventional method by heat produced from products of combustion of a natural gas or oil fired burner, or by heat produced from burning of waste material including wood by-products.

Originally when direct fired kilns were first being manufactured they were only used to fit a specific need, on a specialist basis. For many years it was felt that only steam heated equipment was completely adequate and satisfactory for drying of lumber. I believe the main reason for this was that people felt they had to have steam for humidity control inside of the dry kiln and therefore the only way of heating the kiln was with steam. Originally many plants had large boiler installations and steam was used throughout the sawmill for many uses incidental to dry kilns. Therefore it was a ready heat source and by far the majority of the early built dry kilns were heated with steam equipment.

However, over the past few years changes in sawmill equipment have required less and less steam usage throughout the sawmill. More and more carriages are powered by some source other than steam. Very few plants use steam operated cylinders throughout the plant as was common at one time. Niggers or log turners are now in use that do not require steam and many new mills have been built without steam generating facilities. The great
majority of dry kilns today are still being heated by steam. Over the past few years with this change and require-
ment for steam being diminished throughout the rest of the plant more new operations are considering a heat source
other than the conventional steam method.

For many years Moore Oregon has designed and installed direct fired dry kilns. These direct fired dry kilns
have for the most part utilized a natural gas fired burner. However, dry kilns have been installed utilizing oil fired
burners with a fuel of a consistency no heavier than #2 diesel oil.

Regarding natural gas burners. Natural gas burners have been built and installed as low in size as .5 MM
BTU. As the size of the kilns have grown and the cutting programs changed; the burners have progressively increased
in size. With the advent of high temperature drying we are now manufacturing nearly all burners from 8 to 10 MM
BTU capacity.

Regarding the heat source of a direct fired burner. So far as the heat source itself is concerned a direct fired
system can be used for drying any type of material that can be dried in a steam dry kiln with one exception. Some
items do require close humidity control. I say that a direct fired system can be used with those items because
humidification equipment can also be installed in a dry kiln that does have a direct fired burner as a heat source.
With the installation of this humidification system then you have exactly the same type of control that you would
have with a steam heated and steam controlled dry kiln. However, if the humidification equipment is not available
and the heat source is from a direct fired burner humidification can be controlled only to the point that there is
moisture coming from the wood and therefore regulating the humidity in the dry kiln.

A properly designed direct fired heat system would have the same control of heat and temperature range as
would a steam heated kiln. The direct fired burner if operated on natural gas or oil should have sufficient turn-
down ratio to give the temperature range of operation as desired. In many instances the actual control of the heat
coming into the dry kiln is more accurate with a direct fired system than it is with steam. Because it is very easy
to get an over-ride in the piping system of a steam heated kiln, this can be easily corrected with a direct fired
burner where the burner is merely turned down or shut off when ample heat has been put into the kiln. Through
the control system the heat can be regulated very accurately with a direct fired burner. However, I qualify this to say
that this direct fired burner must be of ample turn down capacity to give you the fluxuation desired. The turn down
ratio on the direct fired burners manufactured by Moore Oregon is a 30 to 1 ratio.

The greatest boost to direct fired heating systems for kilns has been due to many new operations have not
installed steam operated equipment on the construction of a new mill. Therefore they did not wish to construct a
boiler plant simply for the operation of the dry kilns. Many plants have been able to utilize their by-products
or have a sale for them. More and more operations today are using planer shavings for particle board, making
wood chips for paper manufacture, and even have sales for sawdust and bark as a mulch or for other commercial
use. Because they have a chance to sell their by-products they also have successfully avoided a pollution problem
that has been brought to the forefront regarding some older waste fired boilers. However there are waste fired
boilers on the market today that do pass the pollution control authorities requirements. It is a matter of economics
in many plants as to which type of fuel system they wish to use for the heating of a dry kiln. Those plants that
have a sale for the by-products or do not have a present boiler installation, therefore look towards the use of direct
fired burner of some type for heat sources in the dry kiln. With the incoming popularity of high temperature drying
through the last three or four years Moore Oregon has found that the use of a direct fired natural gas burner is more
than satisfactory for a heat source in this type of drying. In fact of the last 32 high temperature dry kilns that
Moore Oregon has sold twenty of these 32 have been heated by direct fired natural gas burners.

We have found through the experience of the last 5 years that drying by direct fired natural gas burners has
been very effective on dimensional items. This would be species of Fir, both Douglas Fir Coast type and Inland
Fir, Larch, White Fir, Hemlock, Lodge Pole Pine, Spruce and fast growing young Ponderosa and what we commonly
refer to as Bull Pine. Direct fired kilns without some type of auxiliary humidification have not been as satisfactory
for use with Ponderosa Pine, Sugar Pine, Douglas Fir upper grades, some types of Spruce, or any species of material
being made into merchandise for remanufacture for mill work uses. The principal disadvantage regarding mill
work items is the fact that humidification is necessary for control of stress relief in equalization of the product.

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However in the dimensional items this has not been necessary and therefore direct fired burners have been satisfactory. Direct fired burning equipment for use in heating dry kilns has also been used extensively in the Southern Pine region. Here we have had phenomenal success with the direct fired kilns and in some instances have installed auxiliary steam spray equipment for equilization of the Southern Pine dimensional material. This has not always been the case though, and the customers seem to be well satisfied with the direct burning equipment without the auxiliary humidification equipment.

One of the advantages to direct firing with natural gas equipment is the principal of putting 95% to 98% of the heat generated by the burner directly into the dry kiln. This is an economical advantage over many boiler installations that utilize either oil fired or natural gas burners on a boiler. The most efficient boiler, or I should say boiler fired by natural gas or some type of oil, will produce and generate steam at the rate of 80% efficiency. Therefore, a 15% to 18% efficiency is gained by a direct fired burner over a package boiler fired by natural gas or oil. This has become particularly important to those operators that do have a sale for their waste by-products and choose to buy oil or gas to fire a boiler.

Moore Oregon has not built very many single track dry kilns utilizing a direct fired system. By far the large majority of the dry kilns constructed over the past several years have been of the double track design. Originally the direct fired heat source was only installed to be blown into the kiln overhead or distributed in a very inefficient manner in the dry kiln. It was then left up to the circulation fans or fan system of the dry kiln itself to distribute the heat evenly. This did not prove to be a very efficient manner.

During the past several years direct fired dry kilns in the double track design have been designed and built with the same heat distribution ratio that we have experienced with steam heated kilns. We have a duct system that distributes the heat throughout the kiln in a uniform manner placing 60% of the heat in the overhead section and 40% of the heat in the center section or booster portion of the dry kiln. This is the same ratio that we use in distribution of the fin pipe or heating coils in a dry kiln that is steam heated.

The most common method used for direct fired heat distribution is the burner located in the overhead control room at one or both ends of the dry kiln. It has been our experience that if we go over 70 ft. in length with the dry kiln that we should locate a burner at each end of the kiln. We have found that it is very difficult to distribute the heat evenly over a length in excess of 70 ft. Therefore on 84, 88, 104, 120 or longer kiln we have a burner system in an overhead control room at both ends of the kiln. These burners then blow the heat through a large recirculation fan into the overhead duct work and down the length of the kiln. This overhead duct work has a louvered system on each side which allows the heat to escape in a uniform manner. This louvered duct system is adjustable to guarantee uniformity of heat distribution. Through this overhead duct we then release 60% of the amount of heat that is being distributed. Then the balance or 40% of the heat being directed from the direct fired burner is distributed down between the loads in a double or triple track through heat duct pipes. These pipes have openings up and down their length which distributes the heat again evenly throughout the booster area. Therefore we get the same type of control and uniformity with a direct fired dry kiln that we previously have always achieved with the steam heated kiln. It is our contention that unless this heat is distributed evenly in the dry kiln you are not going to have uniform drying. As I stated earlier with the longer kilns we have a heat source or burner system at each end of the kiln. This burner system then directs heat towards the center from each end and is distributed as discussed previously. We feel the most efficient manner of locating the burner system is in the overhead control room. This is not mandatory and we have constructed dry kilns with the burner system or systems being located in a control room alongside of the dry kiln. In this system the heat is directed underneath the ground into a duct which then distributes the heat evenly the full length of the kiln and up through the center booster coils and in to the overhead duct. We have allowed for adjustment of all of the heat release points so we can insure uniformity of heat distribution throughout the kiln in the manner that we desire. Again as stated this is in the ratio of 60% of the heat overhead directly into the air circulation fans and 40% into the booster area on a double track or larger dry kiln.

As natural gas has become more available to many areas, it is also becoming better known. Some years ago many people had a great fear of the use of natural gas. However, it has been proven to be a safe fuel supply. As equipment and technology have also improved the natural gas burners now constructed and installed in dry kilns.
are of a fail safe design. We at Moore Oregon have yet to have a serious accident or failure of a natural gas burner. The direct fired heating systems utilizing #2 diesel or a more volatile fuel are equally as safe. There are more adjustment problems with an oil fired direct fired system because of the consistency of the fuel and the fluctuation in flow of the fuel due to temperature changes. Natural gas in most instances gives a very uniform supply at all times.

Firing a direct fired dry kiln with oil other than #2 is not satisfactory. The sulphur content of the heavier oils is very damaging to the metal parts of the dry kiln.

One consideration that should be given, if you are planning to install a natural gas fired dry kiln, is to an auxiliary fuel supply. This auxiliary fuel supply can be supplied with butane or propane. However, there is some rather sophisticated mixing equipment required to automatically go on to the stand-by fuel supply. This stand-by fuel supply would be required if you were to get the best possible commercial gas rate to fire a boiler by natural gas. Therefore, it is not exactly an additional cost required only for a direct fired kiln but for any type of heat source being fueled with natural gas.

For the most part Moore Oregon has attempted to standardize on building design regardless of the heat source. We use an overhead control room for both steam heated and direct fired dry kilns. We can also utilize a ground level control room for either heat system. Building construction is essentially the same with either type of heat source. We utilize the prefabricated aluminum building for high temperature kilns and the building sizes are identical. The only difference in the design relative to a steam heated or direct fired kiln is the duct work in the dry kiln versus the installation of the heating coils. We have also spaced the tracks through a double track kiln a little wider allowing more room between the loads for the direct fired ducts that come down from the overhead duct work to the floor level. We have built direct fired dry kilns of wood construction, concrete and masonry construction as well as prefabricated aluminum. Some people have questioned whether or not a direct fired kiln is more of a fire hazard than the steam operated kiln. We do not feel the building construction is any prerogative or deterrent to the direct fired kiln. Except for high temperatures the dry kiln is being loaded with a flammable material called wood anyway. If it were a fire hazard to use a direct fired dry kiln on any building construction we would be unable to use it to dry wood in any manner. We have designed our direct fired equipment to be safe for any type of building construction. The direct fired burner is set upon a concrete slab in an overhead control room very similar to the motor base of concrete construction that we have used with line shaft dry kilns for many years. The burner system is housed in an insulated metal duct work that is completely fire safe. The controls on the direct fired burner are a double control in all instances. We have a low temperature and high temperature cut off switch. We have two governing valves on the gas train itself. We have a low and high air velocity switches. Fail safe devices on the direct fired systems insure their meeting the codes required in the various areas. However, if you are considering an installation of a direct fired dry kiln you should check with your insurance people in your area to see if they have any particular building or code requirements that we are unaware of. We have found over the past many months that code requirements do vary in areas tremendously. Various county, city and state codes vary considerably and we are not at this time operating under any national insurance code. Your insurance underwriter is the best one to contact in this regard.

The fan system in a direct fired dry kiln can be identical to the fan system in a steam heated kiln. We utilize both the cross shaft and line shaft fan systems with both types of heating equipment. The operation of the fan system cost wise would be identical to that of any other type of dry kiln. A direct fired dry kiln does have a greater horsepower requirement. In addition to the fans and motors located in the dry kiln, or in the control room with a line shaft system, there is a motor running a combustion blower on the natural gas or oil fired burner. There is also a large recirculation fan taking the heat from the burner system and distributing it through the length of the kiln. This large circulation fan varies as to the size of the dry kiln and also the size of the burner system. The burner system of course is sized according to the holding capacity of the dry kiln.

The following slides are illustrative of both steam heated and direct fired dry kilns.

In summary, I would like to point out that we can build a direct fired kiln to dry any type of material. We
may include with the direct fired system a separate or auxiliary humidification system if the species to be dried require humidification. If the humidity in the dry kiln cannot be controlled to a satisfactory level by the moisture coming from the wood then this auxiliary equipment is necessary. Also if equalization and stress relief are necessary at the end of the drying run on the particular items being dried then the auxiliary humidification equipment is also necessary. As I stated earlier direct fired equipment can be furnished for not only drying any and all items but furnished in many varying sizes. It can be designed and installed in a small single track kiln or installed in a large double track dry kiln. Direct fired heating systems are available for both conventional drying temperatures, and high temperatures.

Schedules for operating direct fired kilns are in most instances identical to steam heated kilns. The only variance would be with items that are damaged by wide spreads between wet and dry bulb.

Without steam sprays to raise the wet bulb, dry bulb temperatures must be controlled within safe limits.

The following will give you an idea of the economics of a direct fired heating system.

<table>
<thead>
<tr>
<th>Dry Kiln Holding Capacity</th>
<th>100,000 B. F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Moisture Content Green</td>
<td>75%</td>
</tr>
<tr>
<td>To Be Dried To</td>
<td>15%</td>
</tr>
<tr>
<td>Green Weight</td>
<td>3.5#/BF</td>
</tr>
<tr>
<td>Dry Weight</td>
<td>2.0#/BF</td>
</tr>
<tr>
<td>To Dry From 75% to 15% = Removing 1.2#/H₂O/BF or 120,000#/H₂O</td>
<td></td>
</tr>
<tr>
<td>BTU's Required to Evaporate 120,000#/H₂O = 240,000 BTU's</td>
<td></td>
</tr>
</tbody>
</table>

**Natural Gas Fired**

Cubic Feet of Gas Required @ 1000 BTU's per Cubic Feet = 240 MM Cubic Feet
Average Gas Cost (Coastal Area) $.45 per MCF = $107.00 Gas Cost plus 3% Loss, or $3.21
Total Fuel Cost $110.21 or $1.10/MBF

**#2 Diesel Fuel Direct Fired** (142,000 BTU/Gal.)

#2 Diesel @ $.17/Gal.
1705 Gallons Required to Produce 240 MM BTU's
1705 x .17 = $290.80 plus 3% Loss = $298.80
Total Cost of Fuel $298.80 or $2.98/MBF Dried

**Steam Heated with Gas Fired Boiler**

Steam Required 240,000#
Cost per 1000#/ @ 80% Efficiency is $.542.
240 x $.542 = $130.00 or $1.30/MBF

**Steam Heated with #6 Oil Fired Boiler**

Cost per Gallon #6 Oil @ $.07 Per Gallon
Cost per 1000#/ @ 80% Efficiency is $.56.
240 x .56 = $134.00 or $1.34/MBF

In the example shown consideration is not given to the amount of steam used for conditioning or stress relief with any of the four systems. This would be a relative amount and therefore the cost for that steam produced would be relatively the same regardless of the heat source being placed in the dry kiln. We would estimate a requirement of approximately 4/10 of a pound of steam per board foot for conditioning. Therefore in this dry kiln holding 100,000 board ft. 40,000 lbs. steam would be required for the conditioning. This conditioning period would perhaps extend for approximately 12 hours and would have a pounds per hour requirement of approximately
The initial investment of a direct fired dry kiln is approximately 12% to 15% greater than that of a steam fired dry kiln. However if you have to buy a boiler to provide steam to the steam heated dry kiln this 12% to 15% is immediately eliminated. In fact if you have to buy steam generating facilities only for the conditioning portion to be used with a direct fired dry kiln, the economics of the two systems are about equal. Many plants, however, have steam available for conditioning but do not have sufficient steam available for the drying cycle. Therefore they can utilize a direct fired heating system during the drying cycle and then utilize the available steam for conditioning at the end of the run.

In most instances the decision whether you should buy direct fired heating equipment or steam heated equipment is variable and must be considered on an individual basis. We at Moore Oregon would be happy to work with you in your dry kiln program. If we can be of any assistance to you in recommending the type of equipment that would best suit your operation please call upon us at any time.

EXPERIMENTAL KILN SCHEDULES FOR 4/4 PHILIPPINE MAHOGANY

Mr. Dean W. Huber, Graduate Student
in Wood Utilization
University of Idaho
Moscow, Idaho

Mr. Robert W. Nix, Senior in Wood Utilization - Engineering
University of Idaho
Moscow, Idaho

Introduction

Kiln drying schedules for Philippine Mahogany have been published by several sources; among these are the Forest Products Laboratory in Madison, Wisconsin, and the Forest Products Institute of the Philippines. These schedules are, for the most part, mild and require lengthy drying periods (four to seven days of drying from twenty to six percent moisture content; twelve to fifteen days of drying from green to six percent). (1)

The objective of recent kiln drying studies in the Wood Utilization Laboratory at the University of Idaho was to decrease the drying time of 4/4 Philippine Mahogany with a minimum of seasoning degrade (e.g., collapse, honeycombing, twist, bow, crook, cup). The study consisted of five kiln charges of lauan (charges 1-5) and one charge of apitong (charge 6). Each kiln charge was different in that the temperature settings were variable as was the frequency of changing the settings. A two-hour period of presteaming and poststeaming was used on each schedule.

Kiln Schedules and Results

Due to a limited supply of test material (lauan and apitong), these studies were planned to initiate the program with an established commercial drying schedule and gradually increase the drying severity until collapse and honeycomb occurred. A summary of each schedule is presented in Table 1.

The established commercial schedule which we used as schedule 1 was outlined by the 1968 Kiln Conference at the College of Laguna in the Philippines. The initial drying temperature settings were 150°F dry bulb and 142°F wet bulb, preceded by a two-hour steaming period and two hours of poststeaming for conditioning purposes. This schedule produced degrade-free lumber of 5 to 6 percent moisture content (MC) in six days. (Initial moisture content range was 20 to 60 percent.)

After the presteaming period of schedule 2, the dry bulb and wet bulb temperatures were set at 160°F and 152°F, respectively (12.7 percent EMC). These temperature settings were maintained for 24 hours to establish moisture and temperature gradient throughout the lumber. The temperature settings henceforth were adjusted to an
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