ABSTRACT

Starting with two suspension burners in 1974, SWF Plywood Co. has installed seven additional double vortex wood waste fuel burners as heat sources for veneer dryers to: (a) dispose of wood waste; (b) decrease dependency upon fossil fuels; (c) provide a degree of hydrocarbon emission control; and (d) reduce fuel costs.

In 1976, five SWF plants used 13.9 million therms (1467 TJ) to dry veneer and make plywood from it. A total of 8.2 million therms (865 TJ) came from wood waste. Approximately 60 percent of all energy used, exclusive of electricity, was derived from wood wastes generated in the manufacture of plywood.

INTRODUCTION

The manufacture of plywood is one of the most energy intensive processes in the forest products building materials industry and the majority of the energy is used to dry veneer. With fuel costs rising in the 10 percent plus range annually, it is important to know that the energy is being used efficiently.

Accordingly, the 1976 thermal energy use associated with using gas vs waste wood to dry plywood veneer is compared in this paper. SWF Plywood Co., a subsidiary of Southwest Forest Industries, has five plywood manufacturing plants in the State of Oregon. There are a total of fifteen veneer dryers in operation in these plants, of which five are direct gas fired. The remaining ten dryers are heated by combustion gases from waste wood burners to: (a) dispose of wood waste; (b) decrease dependency upon fossil fuels; (c) provide a degree of hydrocarbon emission control; and (d) reduce fuel costs.

EQUIPMENT DESCRIPTION

VENEER DRYERS

All of the veneer dryers reported on are of the multiple deck, longitudinal type in which each
zone has a pair of large recirculation fans (see Fig. 1). These fans withdraw gas from the drying decks and discharge it into the upper conduit, frequently called a superheater. Before being reheated, the fraction of the gases equivalent to the combustion gas, evaporated water and fugitive induced air flow is exhausted to the atmosphere. Combustion gases are mixed with the remaining flow to increase its temperature to a setpoint usually 50-75°F (28-42°C) higher than the return gas.

GAS BURNER SYSTEM

The gas heated dryers have burners in the superheater (rated at about $30 \times 10^6$ Btu/hr for which a low pressure fan mixes combustion air with the gas (natural or propane). It is seldom that more than $20 \times 10^6$ Btu/hr is needed. Very little connected horsepower is required to provide the necessary heat release.

WASTE WOOD BURNER SYSTEMS

Wood burner systems from two manufacturers are being used. Figure 1 shows an Energex system as the heat source for a veneer dryer. Combustion gas at about 2000°F (1094°C) is blended with return gas from the dryer to a mixed gas temperature of 1200°F (650°C) (See Fig. 2). This hot gas enters

FIG. 1 ENERGEX HEATED VENEER DRYER

FIG. 2 ENERGEX HEATED VENEER DRYER

the superheater at essentially the same location as the gas burner heat does and when mixed with the recirculating gas increases its temperature by
50 to 75°F (28-42°C). The use of return gas for blend down has several advantages. They are:

1. A significant fraction of the hydrocarbons that would otherwise be vented to atmosphere are burned, and
2. Use of the heat content in the return gas reduces the burner heat requirement.

Starting with two suspension burners in 1974, SWF Plywood Co. installed seven additional double vortex burners on as many dryers. These Energex systems require propane or natural gas only to preheat the refractory and initiate combustion. After about 15 min of operation on wood fuel, the gas is shut off and combustion is self-sustaining.

The remaining three veneer dryers are heated by two MCCI systems (one system is ducted to two dryers). These burners require a continuous gas pilot for ignition of the wood fuel; combustion goes to completion in a second refractory chamber, and they also use return gas for blend down.

Both burner systems utilize high pressure combustion air blowers and ancillary fuel processing equipment. The fuel, primarily plywood trim, passes through a hammermill with a 1/8 in. (3.18 mm) sizing screen. As a result, the connected horsepower associated with the wood waste burning systems is much higher than that for the gas burning systems. The system comparisons include this additional power along with that used for conveying and unloading.

RESULTS

COLLECTION OF DATA

As shown on Table 1, where the 1976 energy consumption data for all 15 dryers is presented, Plants 1, 4 and 6 have more than one type of burner system.

The original data from which this table was constructed contained only total plant entries for production, heat input, and electrical input. As a consequence, it was necessary to allocate values of each for the three burner systems in order that comparisons could be made. Accordingly, Plant 3, having only Energex burners, and Plant 5, having only gas burners, were selected as the basis for further calculations.

It is important to note that each plant has gas fired boilers whose output is used for pressing plywood, space heat, etc., and that the total electrical power input (line 15) includes production line motors, dryer fans, lights, etc. Since all of these support functions go into the production of plywood, and are similar for all plants, no effort was made to separate them from the direct drying costs. As a matter of interest, it is estimated that about 50 percent of the gas input in Plant 1 was consumed by the boilers.

Summing the waste wood originated heat input to the veneer dryers (Table 1, Line 10) results in a (natural) gas saving of over 8 million therms (844 TJ). This is nearly 60 percent of the total heat input to all five of the subject plants.

Calculations in support of the energy use values presented in this paper appear in the Appendix and the results are shown on Table 2.

PLANT 3 - TWO ENERGEX HEATED DRYERS

In this plant where all of the veneer is dried by Energex combustion gases, the specific wood-originated heat use is 16.52 therms/M ft² (161.9 MJ/km²) of plywood [3/8 inch (9.52 mm) basis]. Although the 2,085,220 therms (220.002 TJ) is a true heat energy consumption, about 15 percent more veneer was actually dried and in the form of plywood trim that eventually became fuel.

Of the 503,342 gas therms (53.11 TJ) used, less than one percent was consumed by the burners in warm-up and initiation of combustion.

The 20.51 therms/M ft² (201.0 MJ/km²) appearing on Line 3 of Table 2 represent the total combustion gas energy input necessary to produce plywood when the veneer dryers were Energex heated.

The associated specific electric power consumption (Line 4 of Table 2) was 98.05 kWh/M ft² (1055 kWh/km²).

PLANT 5 - THREE GAS HEATED DRYERS

It is significant that the gas heated (only) calculations show that the total combustion gas energy input necessary to produce plywood from green veneer when the veneer dryers are (natural) gas heated is essentially the same as that for the Energex systems (21.04 vs 20.51 therms/M ft²) (206.2 vs 201.0 MJ/km²). One may conclude that use of the wood combustion gases for drying does not reduce the process thermal efficiency but does decrease the use of fossil fuel by about 78.5 percent (16.52/21.04).

Because the connected horsepower for gas burners is negligible, the specific electric power
<table>
<thead>
<tr>
<th>PLANT NUMBER</th>
<th>1</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRYERS, NUMBER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Gas Heated</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2. Energex Heated</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3. MCCI Heated</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>(a) 2</td>
</tr>
<tr>
<td>PRODUCTION - M ft³* (3/8 in. basis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Gas heated</td>
<td>(b) 30,334</td>
<td>-</td>
<td>-</td>
<td>94,198</td>
<td>(b) 31,399</td>
</tr>
<tr>
<td>5. Energex Heated</td>
<td>(b) 137,842</td>
<td>126,232</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6. MCCI Heated</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(b) 71,720</td>
</tr>
<tr>
<td>7. Wood Heated</td>
<td>-</td>
<td>-</td>
<td>(c) 116,720</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>8. Total</td>
<td>168,176</td>
<td>126,232</td>
<td>116,720</td>
<td>94,198</td>
<td>103,119</td>
</tr>
<tr>
<td>HEAT INPUT - Therms**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Gas for (d)</td>
<td>(b) 629,163</td>
<td>-</td>
<td>-</td>
<td>1,981,800</td>
<td>(b) 660,635</td>
</tr>
<tr>
<td>gas dryer only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Wood (e)</td>
<td>2,277,150</td>
<td>2,085,220</td>
<td>2,329,170</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>11. Gas in sup- (d)</td>
<td>549,990</td>
<td>503,342</td>
<td>1,013,280</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>port of wood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(b) 348,629</td>
</tr>
<tr>
<td>12. Total</td>
<td>3,456,303</td>
<td>2,588,562</td>
<td>3,342,450</td>
<td>1,981,800</td>
<td>2,551,164</td>
</tr>
<tr>
<td>ELECTRICAL INPUT - (f) kWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Gas Heated</td>
<td>(b) 1,242,480</td>
<td>-</td>
<td>-</td>
<td>3,858,100</td>
<td>(b) 1,286,103</td>
</tr>
<tr>
<td>14. Wood Heated</td>
<td>(b) 14,336,520</td>
<td>12,377,473</td>
<td>13,296,662</td>
<td>-</td>
<td>(b) 7,898,380</td>
</tr>
<tr>
<td>15. Total</td>
<td>15,579,000</td>
<td>12,377,473</td>
<td>13,296,662</td>
<td>3,858,100</td>
<td>9,184,483</td>
</tr>
</tbody>
</table>

(a) One burner heats two dryers
(b) Values estimated (see Appendix & Discussion)
(c) Energex + MCCI
(d) Propane + Natural Gas
(e) Assumed heating value = 8500 Btu/lb (4.068 MJ/kg)

* 1 M ft² = 92.9 m²
** 1 Therm = 1.055 x 10⁶ J

The consumption of 40.96 kWh/M ft² (440.9 kWh/ km²) shown on line 6 of Table 2 becomes the basic value for making plywood from green veneer. Comparison with the Plant 3 results reveals that 57 kWh/M ft² (98.05 - 40.96) (613 kWh/km²) is directly attributable to the use of the Energex Burner Systems. This is an increase of 139 percent over that for natural gas drying.

Comparisons of total cost of drying by gas and wood waste cannot be made in this paper because data are not available for the many variables that must be taken into account. In an effort to put gas and electric energy on a comparative basis, it is assumed that although the therm-to-kWh energy ratio is 29.3, seven kWh have a dollar value equal to one therm. The resulting equivalent energy values are:

- Gas (Plant 5) = 21.04 therms + 40.96 kWh × 7 = 26.36 equivalent therms
- Energex (Plant 3) = 3.99 therms +
## Table 2: Comparison of Specific Energy Consumption for Wood Heated and Gas Heated Veneer Dryers

<table>
<thead>
<tr>
<th>PLANT NUMBER</th>
<th>(a)</th>
<th>1</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>(a)</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WOOD HEATED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Wood Use - (Therms/M ft²)*</td>
<td>16.52</td>
<td>16.52</td>
<td>19.96</td>
<td>–</td>
<td>–</td>
<td>21.50</td>
<td></td>
</tr>
<tr>
<td>2. Gas use in support (Therms/M ft²)* (b)</td>
<td>3.99</td>
<td>3.99</td>
<td>(c) 8.69</td>
<td>–</td>
<td>(c) 4.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Total use (Therms/M ft²)*</td>
<td>20.51</td>
<td>20.51</td>
<td>28.64</td>
<td>–</td>
<td>–</td>
<td>26.36</td>
<td></td>
</tr>
<tr>
<td>4. Electric power use (kWh/M ft²)**</td>
<td>104.00</td>
<td>98.05</td>
<td>113.92</td>
<td>–</td>
<td>–</td>
<td>110.13</td>
<td></td>
</tr>
<tr>
<td><strong>GAS HEATED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Gas use - (Therms/M ft²)* (b)</td>
<td>20.74</td>
<td>–</td>
<td>–</td>
<td>21.04</td>
<td>21.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Electric power use (kWh/M ft²)**</td>
<td>40.96</td>
<td>–</td>
<td>–</td>
<td>40.96</td>
<td>40.96</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) Values estimated — See appendix and discussion.
(b) Includes input to boilers for pressing, plant heat, and burner warm-up.
(c) Includes continuous pilot for ignition of wood.

*1 Therm/M ft² = 9.80 MJ/km²
**1 kWh/M ft² = 10.76 kWh/km²

98.05 kWh / 7 = 18.00 equivalent therms

The Energex equivalent energy value is 68 percent of that for gas.

**PLANT 1 – THREE ENERGEX PLUS ONE GAS HEATED DRYER**

If the values for specific thermal and electrical energy use determined above are applied to Plant 1 systems (see Appendix), the calculated specific gas consumption for the gas heated dryer was 20.74 therms/M ft² (203.3 MJ/km²). This is within 1.5 percent of the (all gas) Plant 5 value.

The calculated specific electric power rate of 104 kWh/M ft² (1119 kWh/km²) is within 6 percent of the (all Energex) Plant 3 value.

**PLANT 6 - ONE MCCI PLUS ONE GAS HEATED DRYER**

Reinforced by the results of the Plant I calculations, the same assumptions were applied to the data obtained from Plant 6. This results in the following specific values for the MCCI wood burning gas assisted system:

Wood Heat Use = 21.50 Therms/M ft² (210.7 MJ/km²)
Gas Support Use = 4.86 Therms/M ft² (47.6 MJ/km²)
Total Heat Use = 26.36 Therms/M ft² (258.4 MJ/km²)
Electric Power Use = 110.13 kWh/M ft² (1185 kWh/km²)

Applying the previously used conversion of 7 kWh per equivalent therm, the energy value in equivalent therms is:

4.86 + 110.14 / 7 = 20.59

This is a reduction of about 22 percent when compared with gas drying.

**PLANT 4 - TWO ENERGEX PLUS ONE MCCI HEATED DRYER**

All three of the heat sources in this plant are wood fueled, and data are not available to separate
their performances. Results for the total plant show the following specific rates:

**Wood Heat Use** = 19.96 Therms/M ft² (195.6 MJ/m²)

**Gas Support Use** = 8.68 Therms/M ft² (85.1 MJ/m²)

**Total Heat Use** = 28.64 Therms/M ft² (280.7 MJ/m²)

**Electric Power Use** = 113.92 kWh/M ft² (1226.2 kWh/m²)

The associated energy value in equivalent therms is:

\[ 8.68 + 113.92 + 7 = 24.95 \]

Notwithstanding the increased gas and electrical power consumption at this plant in 1976, the relative operating cost was still nearly 6 percent lower than that for the (all) gas dryer plant.

**CONCLUSIONS**

1976 data obtained at five plywood manufacturing plants operated by the SWF Plywood Co. allows the following operating comparisons to be made between ten waste wood heated and five (natural) gas heated veneer dryers:

1. Out of a total of 608,445 thousand square feet (56,526 m²) of plywood [3/8 in. (9.52 mm) basis], 452,514 M ft² (42,040 m²) or 74 percent of the veneer was dried by combustion gases from waste wood fueled burner systems.

2. More than 8 million therms (844 TJ) used in drying originated in wood waste fuel, replacing essentially the same number of gas therms.

3. The total heat required to produce an equal amount of plywood from green veneer was essentially the same for Energex wood burner and gas burner drying. The thermal efficiencies of both processes are therefore considered approximately equal.

4. Use of Energex wood burners for drying only (and gas for other plant uses) reduced the use of fossil fuel by 78.5 percent.

5. The relative energy values of Energex dried vs (natural) gas dried plywood was 18.00 vs 26.36 equivalent therms per thousand square feet of 3/8 in. (9.52 mm) plywood, a net reduction of 32 percent.

**APPENDIX**

**CALCULATIONS IN SUPPORT OF ENERGY USE VALUES**

**PLANT 3 - TWO ENERGEX HEATED DRYERS**

1. Wood use = 2,085,220 ÷ 126,232 = 16.52 Therms/M ft²
2. Gas use in support = 503,342 ÷ 126,232 = 3.99 Therms/M ft²
3. Total heat use = 2,588,562 ÷ 126,232 = 20.51 Therms/M ft²
4. Electric power use = 12,377,473 ÷ 126,232 = 98.05 kWh/M ft²

**PLANT 5 - THREE GAS HEATED DRYERS**

1. Gas use = 1,981,800 ÷ 94,198 = 21.04 Therms/M ft²
2. Electric power use = 3,858,100 ÷ 94,198 = 40.96 kWh/M ft²

**PLANT 1 - THREE ENERGEX + ONE GAS HEATED DRYERS**

1. Estimated production from Energex heated dryers (assuming 16.52 therms/M ft² wood) 2,277,150 ÷ 16.52 = 137,842 M ft²
2. Estimated production from gas fired dryers 168,176 - 137,842 = 30,334 M ft²
3. Estimated gas input in support of Energex heated dryers (assuming 3.99 therms/M ft²) 3.99 × 137,482 = 549,990 Therms
4. Estimated gas use for gas fired dryer (1,179,153 - 549,990) ÷ 30,334 = 20.74 Therms/M ft²
5. Estimated electric power consumption for gas fired dryer (assuming 40.96 kWh/M ft²) 30,334 × 40.96 = 1,242,480 kWh
6. Estimated electric power use for Energex heated dryers (15,579,000 - 1,242,480) ÷ 137,842 = 104.0 kWh/M ft²
PLANT 6 – ONE MCCI + ONE GAS HEATED DRYER

1. Estimated production from gas heated dryer
   (assuming plant 5 is typical) \(94,198 \text{ M ft}^2 \div 3 \text{ gas dryers} = \)
2. Estimated production from MCCI heated dryer
   \(103,119 - 31,399 = \)
3. Estimated wood use by MCCI heated dryer
   \(1,541,900 \div 71,720 = \)
4. Estimated gas input to gas heated dryer \(21.04 \times 31,399 = \)
5. Estimated gas use by MCCI heated dryer
   \((1,009,264 - 660,635) \div 71,720 = \)
6. Estimated total heat use by MCCI heated dryer \(21.50 + 4.86 = \)
7. Estimated electric power consumption by gas heated dryer
   \(40.96 \times 31,399 = \)
8. Estimated electrical power use by MCCI heated dryer
   \((9,184,483 - 1,286,103) \div 71,720 = \)

PLANT 4 – TWO ENERGEX + ONE MCCI HEATED DRYER

1. Wood use = \(2,329,170 \div 116,720 = \)
2. Gas use = \(1,013,280 \div 116,720 = \)
3. Total heat use = \(3,342,450 \div 116,720 = \)
4. Electrical power use = \(13,296,662 \div 116,720 = \)

Key Words
Combustion
Drying
Energy
Furnace
Residue
Waste Heat
Wood

31,399 M ft²
71,720 M ft²
21.50 Therms/M ft²
660,635 Therms
4.86 Therms/M ft²
26.36 Therms/M ft²
1,286,103 kWh
110.13 kWh/M ft²
19.96 Therms/M ft²
8.68 Therms/M ft²
28.64 Therms/M ft³
113.92 kWh/M ft²
This paper presents an interesting case study reflecting the increasing interest shown by industry in using waste combustion systems to reduce fossil fuel purchases. With the new energy economics, many such conversions are cost-effective and represent a technically sound response to national energy conservation policy.

I would be interested in the comments of the authors regarding several questions raised in the paper.

1. Often, the combustion of waste materials produces a much higher particulate loading in the exhaust than the natural gas or No. 2 fuel oil used previously. In this case, did the substitution require installation of air pollution control systems and/or result in any significant contamination of the product with settled particulate?

2. I would be interested in a description of the system used to bunker and feed the wood waste and any special design features which were important to good operation. Was the plant able to get the same degree of heat release rate modulation (turn-down) burning wood waste as was obtained on gas?

3. Finally, did the plant experience any special problems in burner operation due, say, to slagging of ash, build-up of char in ducts, ignition and flame stability in the burner, etc.?

AUTHORS' REPLY

To Walter R. Niessen

My response to the reference discussion is as follows:

1. It is not true that use of wood waste for fuel vs natural gas or No. 2 fuel oil produces a "much higher particulate loading" in the cases reported; the reasons follow:

   It is true that the wood waste has a noncombustible fraction equal to ¼ to ½ percent of its oven dry weight, a contaminant that is not present when natural gas, propane, or light oil is the fuel. Further, this fraction does contribute to the total process emission. If all of this solid particulate left via a stack and there were no additional emissions, the corresponding mass rates would be 0.1 to 0.2 grain per standard dry cubic foot. There are several mitigating influences, however.

   The dryer itself is a "fortuitous collector" and hence it reduces the contribution of the noncombustible fraction to the total emission. Some of this material deposits on the dryer walls and some on the veneer being dried. A calculation shows that the average amount deposited on the veneer does not exceed 0.001 in. in depth, and is almost unnoticeable.

   Instead of being a contaminant of the product, this deposit may be the cause of a glue bond that is even stronger than the very satisfactory bond experienced when gas is the fuel.

   A second mitigating influence is the fact that condensable hydrocarbons and fibers from the veneer being dried contribute more than half of the total stack emissions when wood waste is the fuel. These emissions exist independent of the fuel source.

   I am not aware of air pollution control systems that have been installed on veneer dryers to reduce particulate emissions. For Oregon installations, this is due to the fact that establishment of the regulation is still in process. An opacity (Ringleman) "not to exceed" 20 percent is currently a regulation, but whether to judge particulate emission limits on the basis of a combustion device or a process is the enigma.

   A considerable amount of outside air leaks into the subatmospheric zones of the dryer; correcting the grain loading to 12 percent CO₂ as is usually the case for a combustion device would be an enormous penalty. Establishing an attainable weight loading per unit of production requires the judgement of a Solomon.

2. The wood waste consists, in part, of sander dust, a by-product of sanded plywood. The remainder of the fuel originates as unusable dried veneer and the trim produced when the plywood sheets are cut to size. All of this material has a moisture content of 8 percent (wet basis) or less.

   The veneer and trim is conveyed to a hammermill having a screen with 1/8 in. diameter holes. All of the prepared fuel is then blown into a large surge bin or silo that has a screw type unloader. The unloader feeds a 100 ft³ metering bin that has D.C. motor driven live bottom screws. The heat demand establishes the screw speed and a positive displacement pump is used to air convey the fuel to the burner (up to 700 ft).

   The burners have a 5 to 1 turn-down ratio which is more than adequate for veneer dryers.
Within this turn-down range there is no flame instability.

3. The air-fuel ratio in the burner is maintained at an essentially constant value, so that the combustion gas temperature will also remain nearly constant. If this ratio departs significantly from the prescribed range because of a malfunction, operating problems occur.

When too little combustion air is available, the gas temperature gets too high and the noncombustibles in the fuel melt and become slag. When there is too much combustion air, the residence time of the fuel in the burner is reduced and there is some unburned "carry-over."

As long as the burner is operating within specification, there is no reason for any char to accumulate in the ducts because: (a) combustion efficiencies in excess of 99.8 percent are normal; (b) duct temperatures of 1100 to 1200 F are usual; and (c) duct velocities of 5000 ft/min are common.