SII Dry Kilns present:

Thermal Modification 2017
The process removes moisture and volatiles from biomass leaving “bio-char”
Thermal Modification

- Modified by a controlled “pyrolysis” process of wood being heated (>356 F) in absence of oxygen inducing some chemical changes to the cell wall components (lignin, cellulose, and hemicellulose) in the wood in order to increase its durability.
THE PROCESS OF WOOD THERMAL MODIFICATION WILL CHANGE WOOD PROPERTIES:

- COLOR
- VARIATION OF MASS AND DENSITY
- HYGROSCOPICITY
- DIMENSIONAL STABILITY
- DURABILITY
- THERMAL INSULATION
- MECHANICAL CHARACTERISTICS
Thermal Treated Wood

- Improved durability against decay
- Improved dimensional stability
- Consistent color through the piece
- Emissions, pH ...
- Reduces equilibrium moisture content and wettability
- Reduced thermal conductivity
- Resin removed
- Slightly reduced bending strength
Dr. Ottaviano Allegretti – CNR IVALSA

PROCESS VARIABLES

T Temperature

- Reversible phenomena
- Modification range
- Possible treatments range
- Industrial treatments range
- Fire point with O2
- Cellulose starts degradation
- Fire point without O2
- Hemicellulose exothermic degradation
- Lignin exothermic degradation
- Liquid and gaseous formation

Ignition temperature °C

Working range of Thermal treatments
COLOR VARIATION

Variation and homogenization of color throughout the thickness of the wood occurs, the intensity of which can be controlled through appropriate adjustments of treatment parameters, namely:

- temperature
- pressure
- exposure time
FIR

Abete bianco
NON TRATTATO

Abete bianco
T = 160°C per 15 ore
WVP = 200 mbar

Abete bianco
T = 190-200°C (8h)
WVP = 200 mbar
OAK

QUERCIA
T = 160°C (15h)
Vw 01 = 100 mbar

QUERCIA
T = 190 - 200°C (8h)
Vw 01 = 200 mbar
Variation of mass and density are important index of thermo-chemical processing.

No mass variation means no thermal treatment
Cherry

TG = Thermogravimetric mass

DTG = thermogravimetric Mass change

Formation of gas, Acetic acid, Formic acid, etc.

TG = Thermogravimetric mass

DTG = thermogravimetric Mass change

Formation of gas, Acetic acid, Formic acid, etc.
LIGNIN

TG = Thermogravimetric mass

DTG = thermogravimetric Mass change
CELLULOSE

TG = Thermogravimetric mass

DTG = thermogravimetric Mass change
HEMICELLULOSE

TG = Thermogravimetric mass

DTG = thermogravimetric Mass change
Reduction of wood hygroscopicity, i.e. its ability to absorb or expel the humidity of the surrounding environment, making it almost insensitive to weather changes (temperature and humidity)
DIMENSIONAL STABILITY

As a result of the reduction of hygroscopicity, the wood acquires a great dimensional stability with respect to variations of ambient humidity, the effect of which is reflected in the quality of finished products (furniture, flooring, doors, musical instruments etc.) that become practically insensitive to climate changes.
MECHANICAL CHARACTERISTICS

- Working at temperatures not exceeding 230°C, it has been detected some deterioration of some mechanical characteristics, but a slight improvement in the hardness, after that mechanical characteristics get worse rapidly.

- In other words, the heat-treated wood becomes a more fragile, but little harder.
STATE OF THE ART

Main methods currently used in industry:

1. Cell at atmospheric pressure in superheated steam atmosphere (open process)

2. Cell saturated with nitrogen at atmospheric pressure (open process)

3. Autoclaves in pressure with saturated and / or superheated steam (closed process)
A) To avoid the collapse of the cell walls, before treatment, the wood must be dried to moisture levels close to 0%.

B) The internal atmosphere should be kept inert to prevent ignition of combustion.

1. **Preheating of the wood** until it reaches the start temperature of pyrolysis of about 160-180 °C: during this period the wood loses the residual moisture.

2. **Proper thermal treatment**, that consists in keeping the timber at the selected temperature for a predetermined time.

3. **Cooling of the wood** until it is below 100 °C, to be able to subsequently expose to the external environment without the danger of combustion and/or problems of thermal shock of woody matter.
PROBLEMS

Heating:

Depending on the type of treatment, the site requires the installation of:

- Steam boiler
- Thermal oil boiler

For this reason the installations are expensive and complex and require permits, inspections and maintenance.
PROBLEMS

Inertization obtained by:

1- nitrogen
2- superheated steam
3- saturated steam under pressure in autoclaves

This means:

- Risks in case of lack of electricity and / or gas leaks.
- Use of autoclaves in pressure
- Costs and / or supply of such gases / vapors.
PROBLEMS

Cooling obtained by water spray:

To reduce the wood temperature from 230 °C down to 100 °C, it’s necessary to introduce in the cell:

70-80 liters of water per m³ of wood

This corresponds to a production of about 150 m³ of polluted steam per m³ of treated wood.
PROBLEMS

Emissions in the atmosphere and pollution:

A 10 m³ cell produces at any cooling phase approximately 1,500 m³ of steam, which is potentially polluting and definitely has an odor.
SAFETY:

Risk of fire in the event of:

- lack of power supply
- entry of air for condensation of the superheated steam
- lack of nitrogen, for gas leaks
Problems referred to the treatments in pressure vessel

Scientific researchers in the field of heat treatment of wood have shown the following:

1. The temperature range to obtain an efficient process of wood pyrolysis is in the range of 180-230°C (Picture A2)
2. Below 180°C the mass loss of the wood is very small and this shows the modest value of modification of the physical characteristics of the wood (Picture B)
3. The hygroscopicity of wood treated with initial humidity of 0% is reduced by 50% compared to that obtained with wet wood treated in pressure vessel.
4. The dimensional stability of wood treated with initial humidity of 0% has an improvement of 50% compared to that obtained with wet wood treated in pressure vessel.
Problems in pressure treatment

Picture A2

ThermoVacuum treatment:
1. Correct mass loss
2. Good thermal modification

Pressure vessel treatment:
1. Small mass loss
2. Poor thermal modification
3. Also with a longer treatment time the mass loss remains small
Problems in pressure treatment: Picture B

Hysteresis of Equilibrium Moisture Content: comparison between ThermoVacuum (TVS) and High Pressure Close System (HPCS)

- **HIGH PRESSURE**:
  - High EMC after treatment
  - Low dimensional stability

- **WDEMASPELL**:
  - Low EMC after treatment
  - High dimensional stability

**EMC**

**RH% = Air Relative Humidity**
HOW

YEAR 2007:

Customers asked WDE MASPELL to modify their vacuum drier in order to use it also as a chamber for wood thermal modification.
Year 2008

Cooperation agreements between:

- CNR IVALSA (Italian Wood Institute)
- UPPSALA UNIVERSITY - Sweden
- WDE MASPELL srl

For the research, study and development of the system

“ThermoVacuum”
WHERE: AT CNR IVALS A INSTITUTE

PROTOTYPE FOR LABORATORY
WHERE : AT CNR IVALSA INSTITUTE
Wood subjected to Thermo-Vacuum treatment

- Improved dimensional stability
- Reduced equilibrium moisture content and wettability
- Increased thermal insulation
- Negligible reduction in mechanical strength
- Odourless wood
- Eco-friendly process: no emissions
- Uniform colour throughout the piece
- Enhanced durability and resistance to atmospheric agents
MAXI  30  30 m³
ThermoVacuum?

DESIGNED TO SOLVE THE PROBLEMS OF HEAT TREATMENT PROCESS CURRENTLY USED
SUMMARY OF MOST COMMON TROUBLES OF CURRENT TECHNOLOGIES

- DRYING
- HEATING BY OIL or STEAM
- INERTISATION BY STEAM or NITROGEN
- COOLING BY WATER SPRAYING
- POLLUTION - EMISSIONS IN AIR
- INABILITY TO WORK MORE THAN 180 °C
- SAFETY
Heating: by electricity

![Diagram showing heating system with labels for inside fan and heating coils.]

- **Inside Fan**
- **Heating Coils**
Patented “Longitudinal-Lateral” Ventilation LO-LA System:
INERTISATION

Thermo -Vacuum

a “self inertizing” system

THAT DOES NOT REQUIRE
STEAM or NITROGEN
SELF INERTIZING

- The combustion of the wood needs oxygen.
- The vacuum created in the cell decreases dramatically the amount of oxygen contained in it, making remote probability of initiation of combustion.
- Any insignificant residual oxygen could give rise only to a micro-combustion of an infinitesimal portion of woody matter, after which the combustion would stop for lack of oxygen (experience of the candle in the glass).
COOLING OF THE WOOD

No water spray is required

- The drying chamber is equipped with an external jacket concentric to it, forming an air gap
- A fan provides for circulation of the ambient air in the gap, without it being in contact with the internal atmosphere of the cell
- The ambient air takes heat from the surface of the inner cylinder, which thus arranges the cooling of therein contained wood
COOLING SYSTEM

- COOLING FAN
- AIR JACKET
- LOWER SNORKEL
NO POLLUTION - EMISSIONS

- The vapors sucked by the vacuum pump are converted into liquid by the condenser and then stored in a tank to be disposed of according to law.

- The cooling of the wood does not produce any pollutant steam.
SAFETY

- The plant is self-inerting and therefore intrinsically safe
- An UPS power supply is able to power the PLC control system and the main controls for at least 6 hours
- In case of failure and/or power failure, the PLC can activate a phone dialer that alerts the operator (up to 10 people)
- In case of major alarm, the PLC will inject nitrogen into the cell
Thermo -Vacuum

FINAL SUMMARY

- It is a multi-purpose machine, as it can be used both for drying and for thermal wood modification.
- As a drying tool it can dry any wood species.
- It does not require steam for creating an inert environment inside of the cell.
- It does not need nitrogen for creating an inert environment inside of the cell.
- It does not consume water for cooling the wood mass.
- Despite being intrinsically safe, it is equipped with alarms and means adapted to solve any situation.
- It is equipped with Internet remote control.