CENTER FOR ADVANCED RESEARCH IN DRYING

A National Science Foundation Industry/University Cooperative Research Center

Experimental Study of Drying of Paper with Ultrasound Mechanism

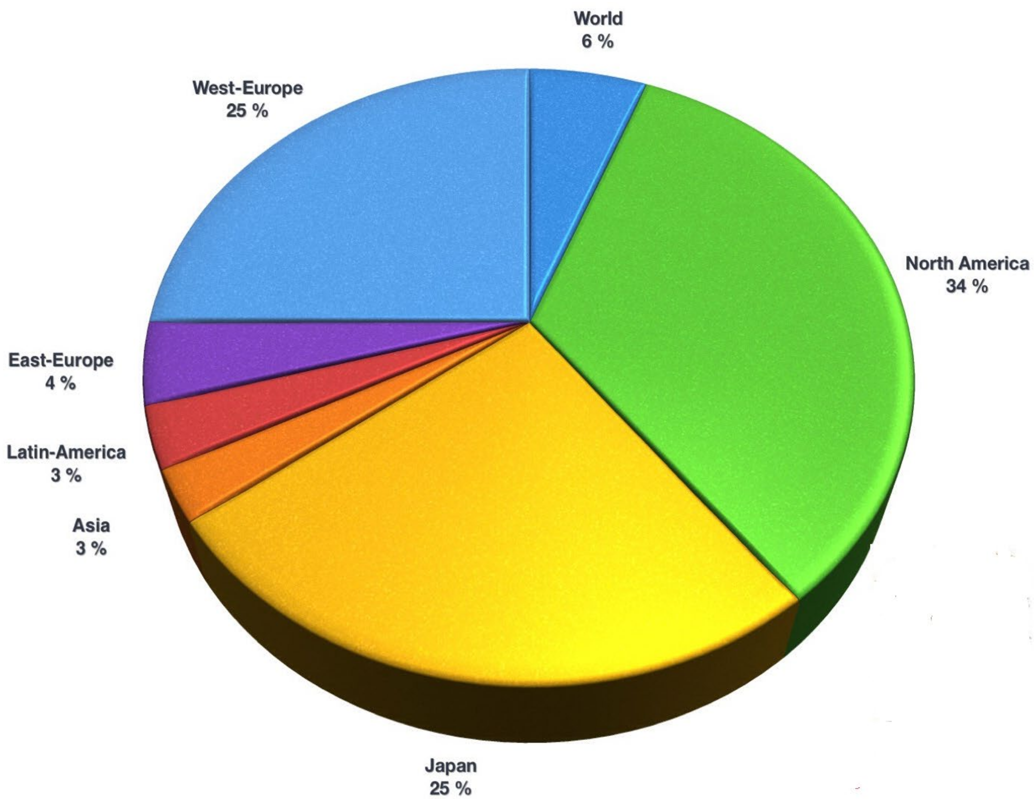
Zahra Noori

Prof. Jamal Yagoobi   Prof. Burt Tilley

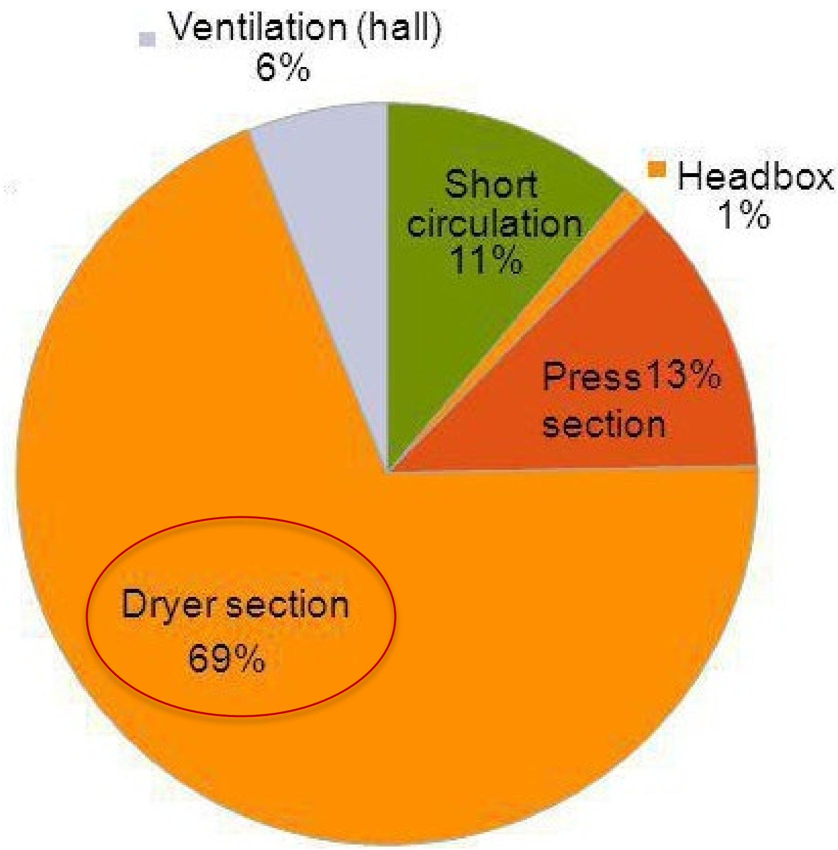
Sustainability Project Competition
April 2022


Kimberly-Clark
Viva
Pull-Ups
Cottonelle
Scott

World paper consumption



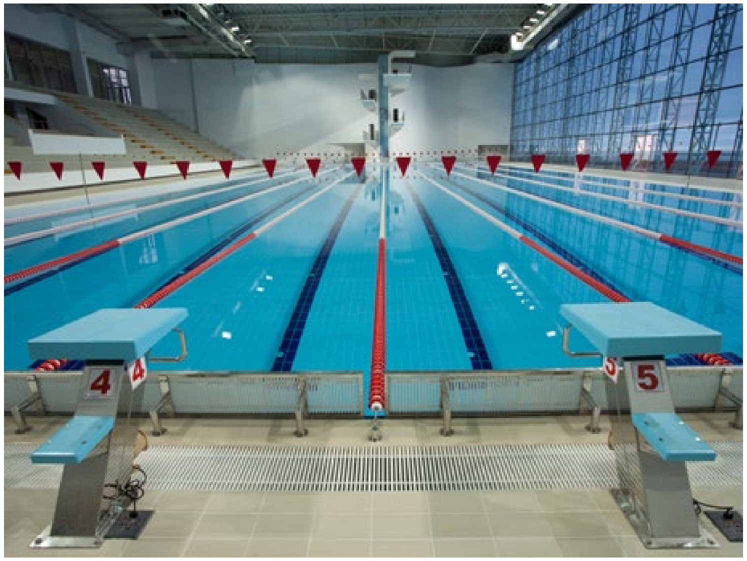
Energy consumption in papermaking machine



Impact of Developing New Technologies

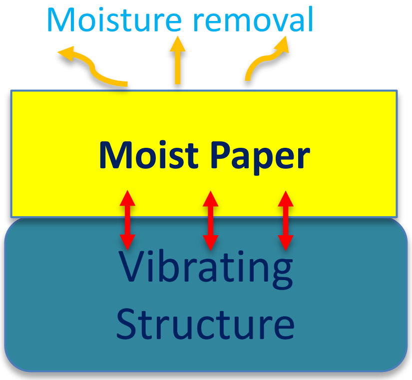
- To save 36 millions of barrels of oil yearly in USA

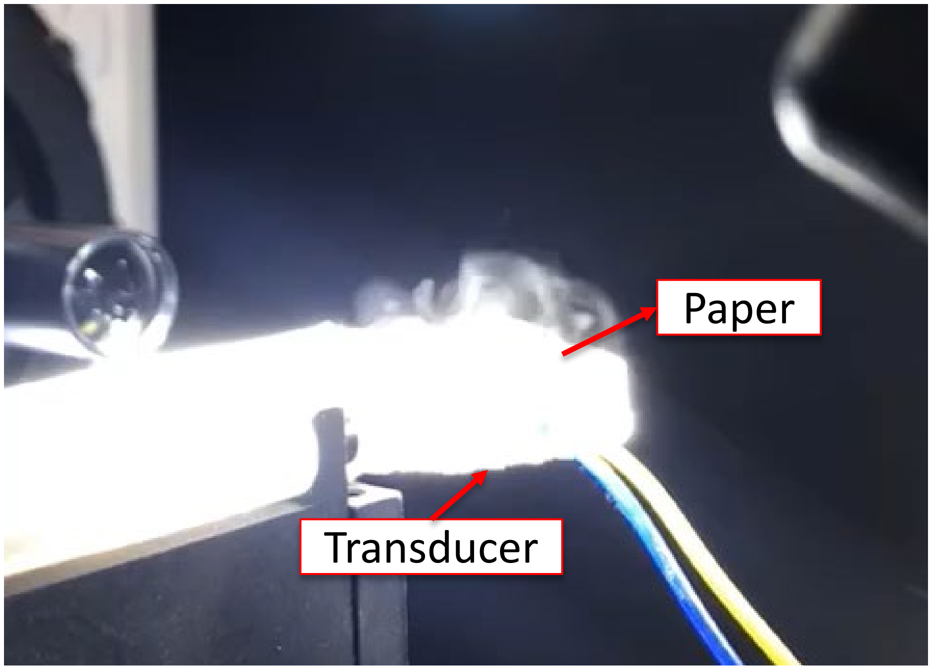
- To save 4,000 Olympic-sized swimming pools of water yearly in USA



Objectives

❖ Ultrasonic drying of paper



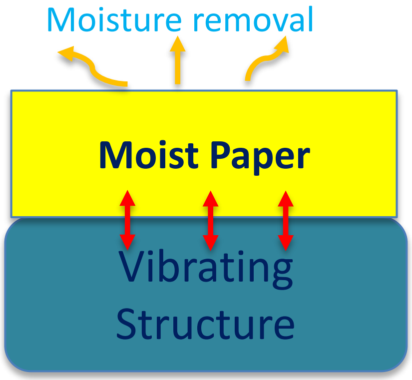


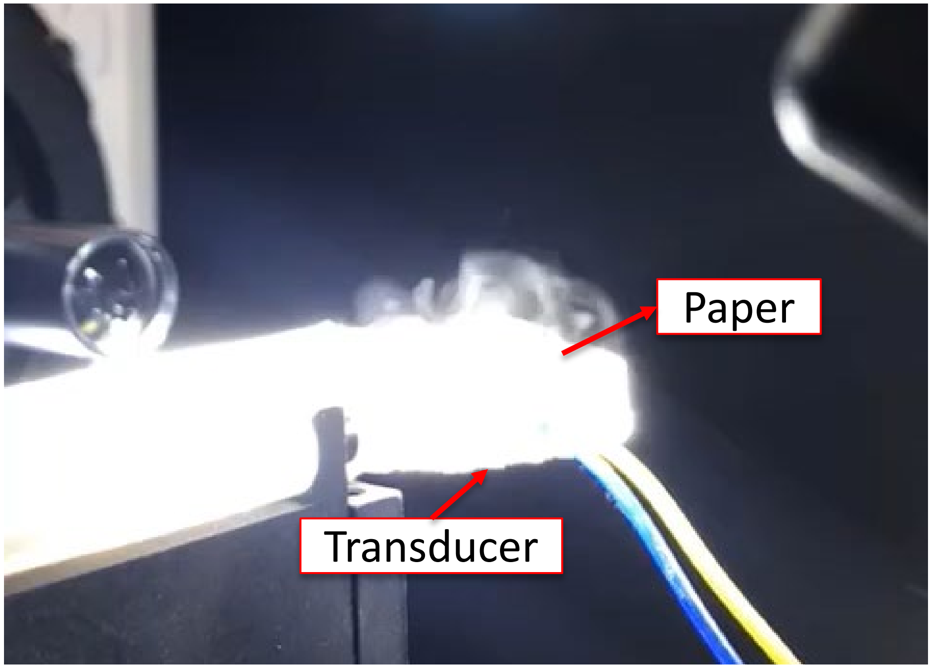
Ultrasonic drying of an over-saturated paper sample.

- ✓ Input power = 10 W
- ✓ Frequency = 1.7 MHz
- ✓ Transducer type = PZT mist generation transducer

Objectives

❖ Ultrasonic drying of paper

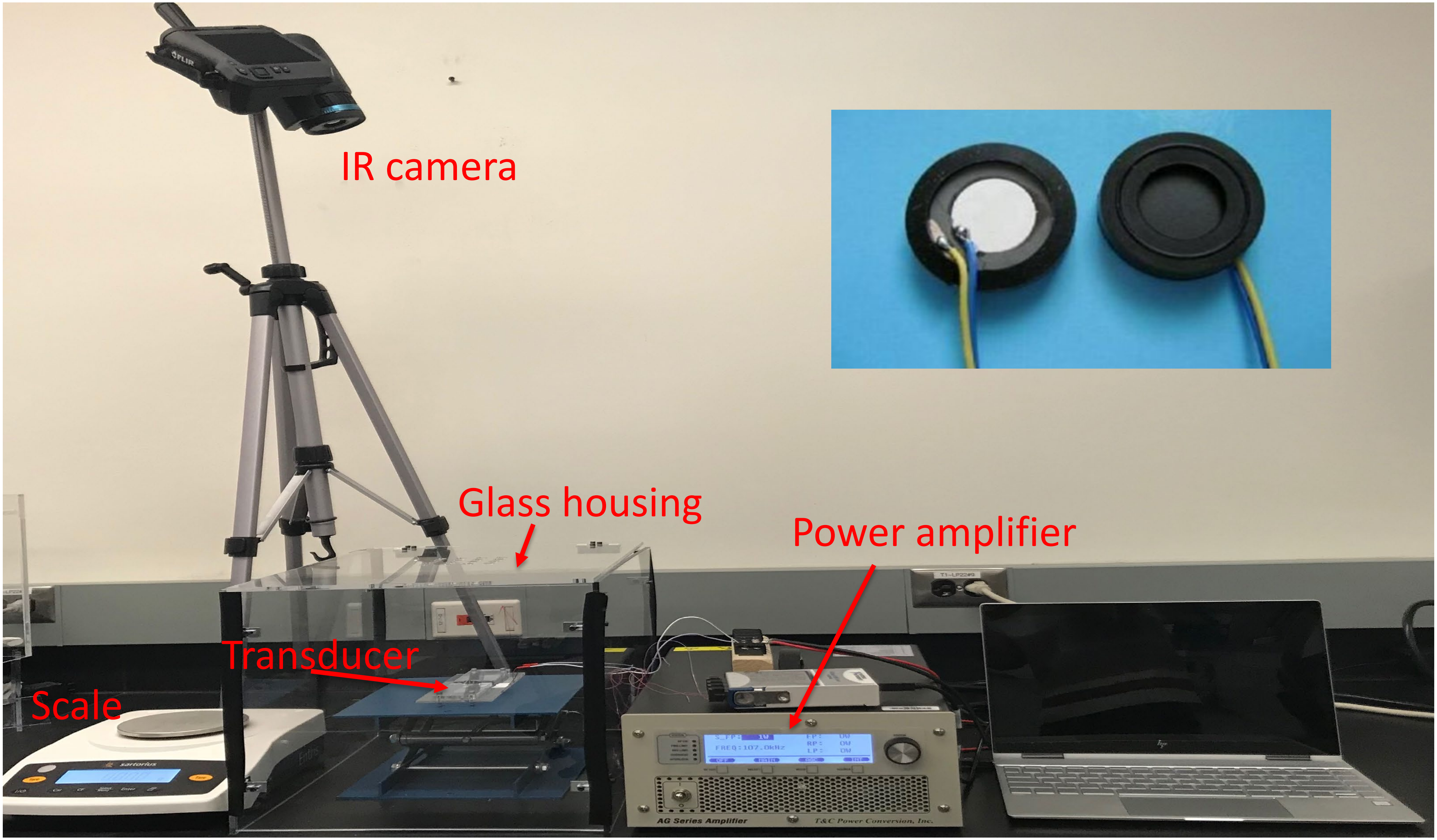




Ultrasonic drying of an over-saturated paper sample.

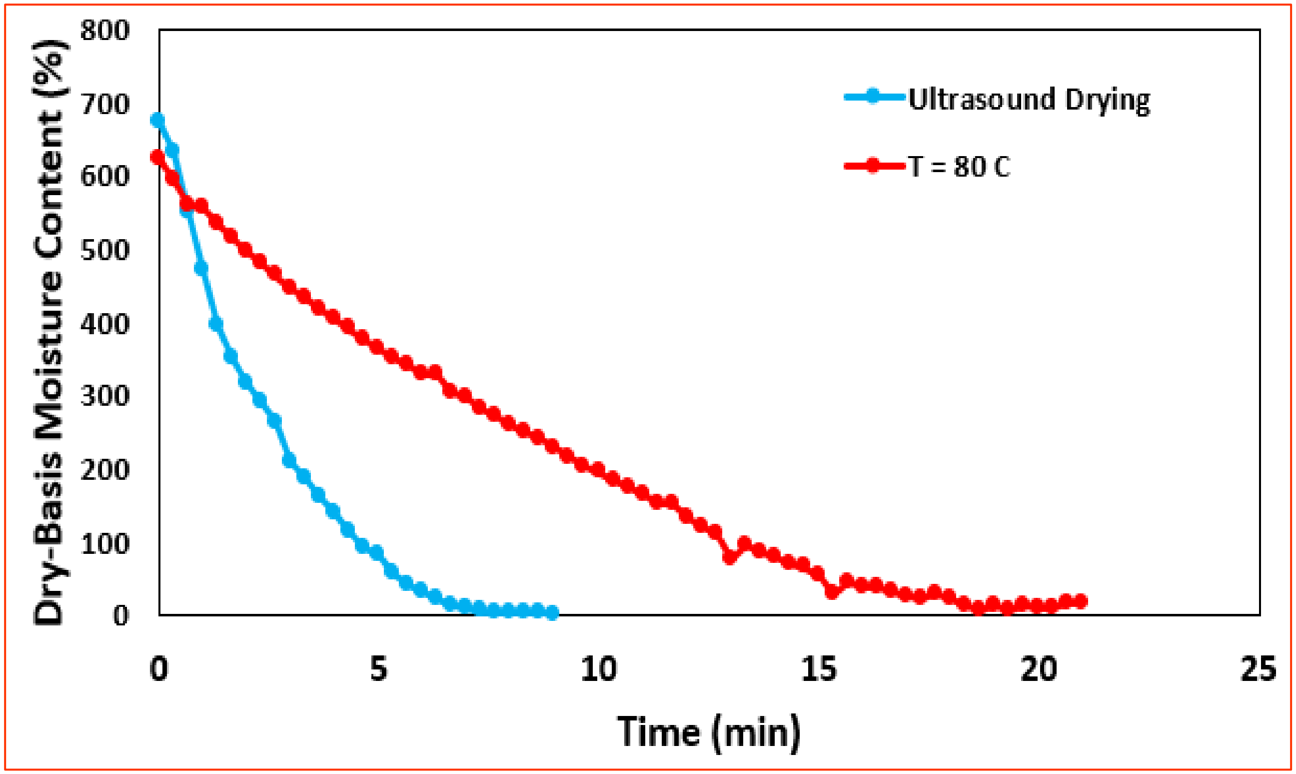
Advantages of ultrasonic drying:

- Lower drying time
- Higher energy efficiency
- Lower temperature for drying (non-thermal)
- Improvement of product quality
- It is a green technology

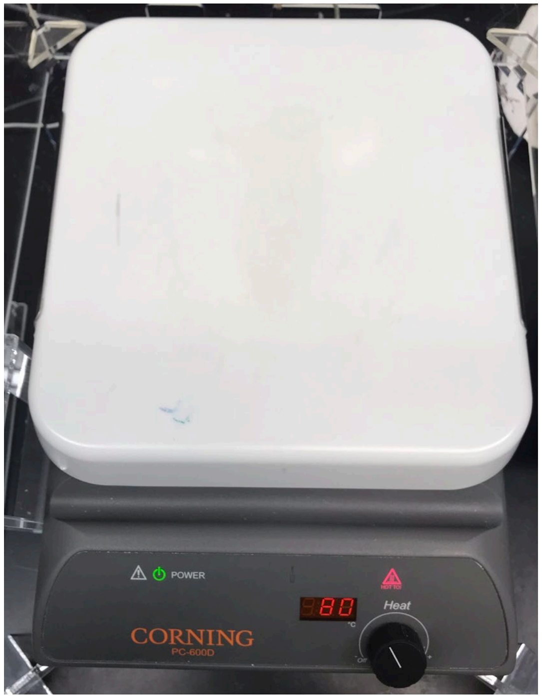


The major components in the experimental setup.

Results



Comparing the drying curves for **ultrasound drying** (1.725 MHz and 10 W.) and **conductive heating**.



The hot-plate unit used for conductive heating.

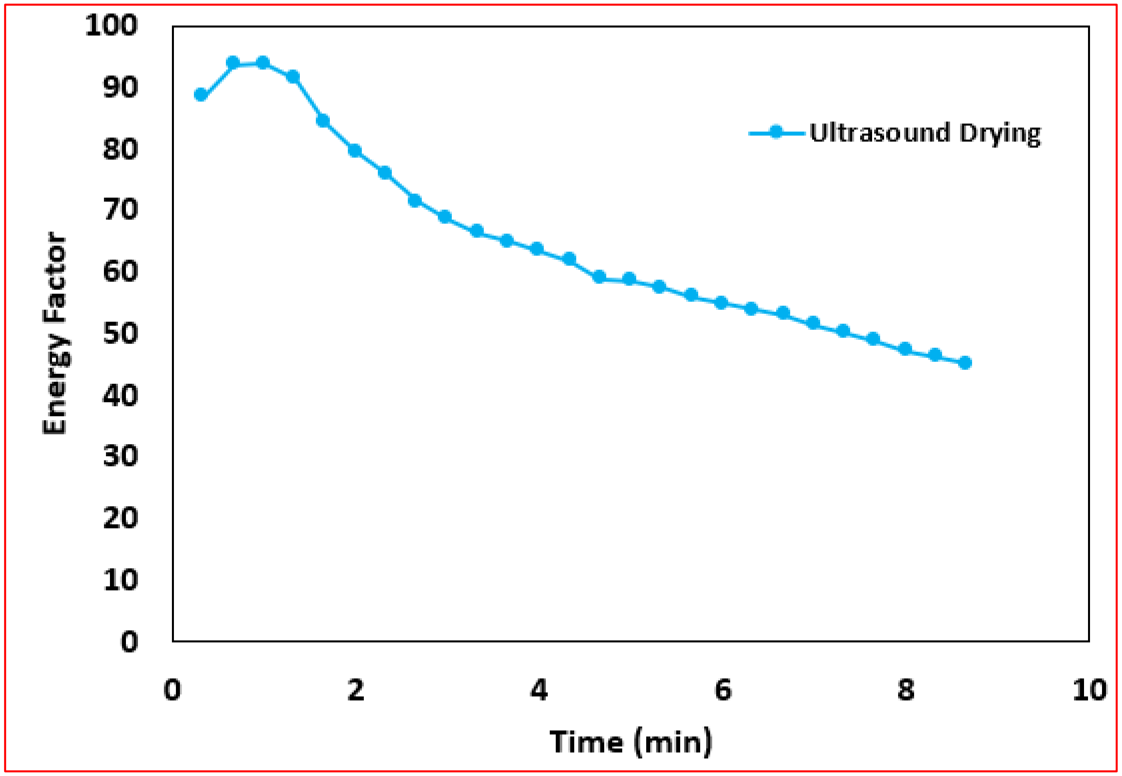
*Max standard deviation is 0.11.

Results

Energy Factor (EF)

$$\mathrm{EF} = \frac{(m_t - m_0) \ * \ h_{fg}}{\int LP(t)dt}$$

t: time
m: mass
h_{fg}: latent heat of water
LP: load power



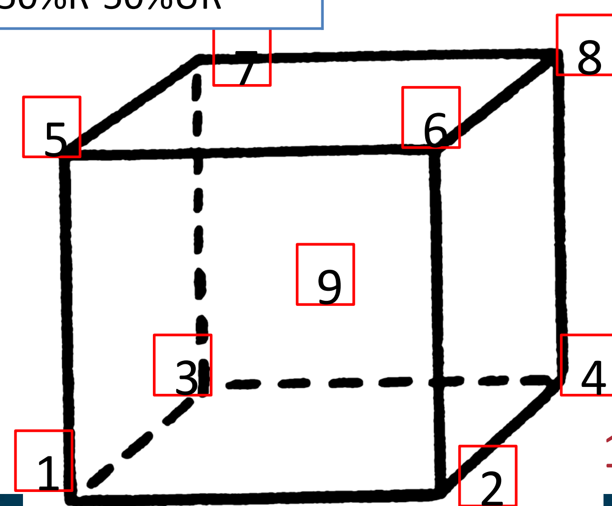
Comparing the energy factors for different transducers and hand-sheet thickness = 0. 8 mm.

- ✓ Ultrasound drying can increase the energy efficiency by almost 40-90 times.

2^3 Factorial Design

2^3 Factorial design of experiments for hardwood

Experiment Number	Factors		
	Initial Moisture Content - DBMC (%)	Basis Weight (gr/m^2)	Refining Condition
1	119	152	Unrefined
2	149	152	Unrefined
3	119	304	Unrefined
4	149	304	Unrefined
5	119	152	Refined
6	149	152	Refined
7	119	304	Refined
8	149	304	Refined
9	134	228	50%R-50%UR



2^3 Factorial Design

Total Drying Time (sec) = C_0 + C_1 * (Initial MC) + C_2 * (Basis Weight) + C_3 * (Refining Condition) + C_4 * (Initial MC) * (Basis Weight) + C_5 * (Initial MC) * (Refining Condition) + C_6 * (Basis Weight) * (Refining Condition) + C_7 * (Initial MC) * (Basis Weight) * (Refining Condition)

R-Sq = 99.47%

Term	Coef.
Constant	108.111
Initial MC	-0.222222
Basis Weight (g/m2)	0.330409
Refining Condition	24.6667
Initial MC*Basis Weight (g/m2)	0.00146199
Initial MC*Refining Condition	-0.333333
Basis Weight (g/m2)* Refining Condition	-0.085526
Initial MC*Basis Weight (g/m2)*Refining Condition	0.00219298

In the above equation, since the Refining Condition is qualitative:
Refined pulp → Refining Condition = 1
Unrefined pulp → Refining Condition = -1

Expected Impact and Future Plans

- ✓ Providing the Pulp & Paper industry with basic understanding of ultrasound mechanism for water removal under various operating conditions.
- ✓ Reducing the temperature and time for drying (energy savings).
- ✓ Improving the product quality.
- ✓ Contributing to the design of smart dryers.

Thank you for your attention :)

For more information contact:

Zahra Noori
znoori@wpi.edu