# <u>ZAP!</u>

## Engineering Wood with Microwave and Radio Frequencies

**by Bridget Mintz Testa**

Improperly cured glue is one of the worst things that can happen to an engineered wood product. When glue doesn't cure properly, the results can include delamination, loss of structural integrity, and inutility. Conventional hot- and cold-press methods work, but two technologies are *operating commercially* right now that offer improvements over these traditional processes by reducing factory space, manpower and time, and by increasing productivity and quality.

### Glue and the Physics of Radio and Microwave Frequencies

The first technology is the application of radio frequencies (RF) to heat the product, thus curing the glue and effecting the bond. The second technology is the application of microwave (µW) frequencies to pre-heat the product and the glue and help effect the bond. RF has been around for years in the engineered wood industry, but hasn't been properly understood or used. Microwave has been around for a while in the forestry lab, but as a commercially viable technology, it is brand new to the industry.

Both RF and µW are portions of the continuous electromagnetic (em) spectrum, which includes radio waves, broadcast television, shortwave, infrared, visible light, ultraviolet, X-rays, and gamma rays. There are no gaps in the spectrum, and no "end" on either side — waves tens of thousands of kilometers long have been measured, and so have waves that are billionths of a meter in length.

To understand how RF and µW work, let's look at how food gets cooked in a microwave oven. A µW, like any em wave, is comprised of an electric and a magnetic portion that look like sine waves vibrating at right angles to one another. For all practical purposes, such as those discussed in this article, the magnetic portion of the wave can be ignored. What's left is a vibrating electric field that changes polarity (positive/negative charge) according to the frequency of the wave. So for a microwave oven, operating at a frequency of 2.45 gigaHertz (GHz - billions of cycles per second) any spot within the oven is going to be changing from a positive to a negative charge and back again 2,450,000,000 times per second.

Food contains water molecules, and these are made up of two hydrogen atoms and one oxygen atom. Although a water molecule is, overall, electrically neutral, within the molecule, it's charged. Specifically, the side with the hydrogen atoms is positively charged, while the oxygen atom side is negatively charged. Thus, the molecule is *polar*.

When a water molecule is exposed to an electric field like the one produced in a microwave oven, the changing electric field in the oven twists the molecule around by its charges 2.45 billion times per second. Bounce a water molecule around a few billion times a second like this, and it gets hot and heats up everything around it. That is how food cooks in a microwave oven.

So how does this apply to engineered wood? Molecules in the glues that bind layers of wood together are polar, just like water (although glue molecules are much larger than water molecules). So when they are exposed to RF or µW, they bounce around just like water molecules in a microwave oven. They heat up, polymerize, and bond to the wood. Water molecules in the wood heat up, too, but that is a secondary bonus effect — the main effect is on the glue.

If the physics of RF and µW as applied to glue are so similar, can there be any differences between them? Yes. RF and µW are different not only in history, but in the products they are used to manufacture, and in the way they are applied.

**Applying RF to Engineered Wood**

The first use of RF in the wood products industry was for plywood, immediately following World War II, according to Bill Barkley, who is now retired and living in Fair Oaks, CA after a 47-year career in the vacuum tube industry. "Mainly due to the extent of development of the technology in and after the war, everything was going to be electronic," he says. Because plywood was very popular after the war, it was natural to apply the new, exotic technology of RF to this new and modern material. However, Barkley says, "RF wasn't really justifiable for plywood. It doesn't pay for thinner products."

Today, one of the primary applications for RF is for glulam, such as that manufactured at Anthony Forest Products in El Dorado, AK. The company makes a variety of trademarked glulam products, including power beams, columns, headers, power logs for log homes, scaffolding, and more.

"The lumber is fingerjointed and glue is applied to the joint," says plant manager Chester New. "It travels through a 30-foot RF tunnel and is cut to length. Then the product travels through a glue applicator and into one of three 20-foot batch presses with SRT generators. The RF cures the glue for the fingerjoint and face bonding by heating the glue to 200-plus degrees Fahrenheit."

The generators New describes are designed and manufactured at SRT Electronics in Puyallup, WA. Steve Tillett founded SRT Electronics in 1984 after working for 12 years as a service manager and troubleshooter for a company that built RF equipment for the forest products industry. Initially, SRT Electronics did consulting and serviced and rebuilt existing RF generators. In 1994, Tillett added in-house generator design and manufacture.

RF is applied by direct contact to the glue line of a product. Tillett explains, "We place two aluminum plates such that one is on each side of and perpendicular to the glue line. RF energy with a frequency of 3 MHz to 20 MHz is then applied to the plates in the form of high voltages of 5,000 to 16,000 V. The RF reacts with the water, salts, and so forth within the glue line, creating heat through molecular agitation. The current passes directly through the glue line, with the greatest potential difference at the center. The glue line reaches the boiling point within one or two seconds, while the wood on either side is still at room temperature. Moisture works into the wood cells, and the zone around the glue line starts heating up. This becomes a conduction zone, where heat can be stored for at least an hour, producing a very deep and complete cure."

The benefits of RF are numerous. New says, "We have increased productivity to approximately twice that for the normal cold-set process. For example, a product batch of about 800 to 1,000 feet in length, of approximately 7.25 inches thick (using 2 X 6 or 2 X 8 lumber) requires about eight minutes to cure with RF instead of hours with a cold or hot press. Not only have we cut our process time in half, but the products are more stable. We also have more versatility in the size and type of products we can make — with a cold-set press, we could only make products of one size." Because the RF equipment is automated, manpower needs are reduced. Finally, the floor space required at the facility is one-half to one-third that which would be required if Anthony Forest Products used more conventional methods.

Years ago, RF gained a bad reputation in the lumber industry due to problems with electric arcing from moisture in the wood. Combined with a general lack of understanding about the technology, the bad reputation lingers. One of Tillett's main goals has been to "dispel some of the myths and black magic" associated with RF. In addition to helping customers understand and use the technology, Tillett has also designed and built unique solid-state sensing circuits into SRT's generators that reduce the danger of arcing to nearly zero. New says, "A long time ago, we had arcing problems, but not with the SRT generators." However, Tillett cautions that if raw wood has a moisture content of 18% or more or, RF arcing will still occur. Thus, RF shouldn't be applied to green wood.

According to Barkley, the capital required to establish and maintain an RF-equipped lumber facility is greater than that for more conventional methods. "A lumber mill isn't the ideal place to operate vacuum tubes," he says. However, since the market demands thick and/or long products and since today such products must nearly always come from gluing together many layers or lengths of wood, RF can offer superior performance and productivity because of its very quick inside-out cure of the glue.

**Applying µW to Engineered Wood**

Microwave is much newer than RF. MacMillan Bloedel began experimenting with the technology in the 1970s and began using it commercially for its trademarked parallel strand lumber product, Parallam®, in 1982. In 1991, Trus Joist and MacMillan formed a partnership to manufacture Parallam. Trus Joist, MacMillan Bloedel, the Trus Joist-MacMillan partnership, and Parallam are now all owned by Weyerhaeuser (Federal Way, WA).

The first use of microwave for wide-billet laminated veneer lumber (LVL), according to consultant Tam Tekle of TTS, Inc. (Edmonton, Alberta), was at Sunpine Forest Products (Rocky Mountain House, Alberta). Tekle was a member of the technical staff at Sunpine in 1997, when the facility was owned by Bruce Buchanan, whom Tekle describes as a "visionary." Sunpine (sold in 1998 to Weldwood, an International Paper subsidiary) was actively seeking to use specialized microwave technology for continuously manufacturing wide-billet LVL, and that was one of the main reasons Tekle went there. Sunpine was in contact with Engineered Wood Energy Systems (EWES - Boise, ID) and its owner, Dieffenbacher Presses (Eppingen, Germany), seeking expertise in designing, building, and supporting the planned microwave system.

RF Technologies Corporation (RFT - Lewiston, ME), founded by George Harris, had been doing high-profile work with high-power RF and µW since 1991 for commercial, military, and government clients. When EWES and Dieffenbacher Presses learned of RFT's work, they asked the company to work on the Sunpine project.

RFT eagerly took on the challenge. In the pre-heating µW system used at Sunpine, the microwaves are generated by magnetrons, just as in a microwave oven. RFT's magnetrons can generate 10 to 100 kilowatts each, at frequencies of 915 MHz in North and South America and 922 MHz in New Zealand and Australia. The total microwave energy generated can be divided by means of several applicators (designed and patented by RFT), which are located both above and below the LVL billet. A typical system may have three generators and 12 applicators, with six above the billet and six below.

George Harris says, "The microwave energy is dynamically controlled using a reflective device called an image plane." This device is an aluminum plate — a mirror for microwaves. An image plane sits on both sides of the LVL billet, reflecting microwaves back to the applicators and thus to the generator. A control system automatically compensates for the reflected microwaves, ensuring that energy application is optimal and that there are neither hot nor cold spots. Harris says, "The microwaves are instantaneously converted to heat in the whole LVL billet, with concentrated heat in the interior." So the glue is rapidly pre-heated to the desired temperature range ($175^{o}$ - $190^{o}$ F), after which the LVL billet is conveyed into the hot press for the final cure.

The benefits achieved by pre-heating the LVL billets mean that Sunpine reaps distinct advantages over competitors. Chris Baby, plant manager, says, "The microwave pre-heating process cuts our press cycle time from about 18 minutes with conventional continuous press methods to about 9 minutes."  Because the microwave process is so fast, it also reduces the danger of glue dry-out during the lay-up stage.  Since the microwaves heat up and soften the region around the glue line, Baby says, "We get a more pliable interior, so compression (in the continuous press) is more even, producing a lower coefficient of variability (COV) in the final product."  LVL panels of up to five inches in thickness can be produced with only one pass through the µW pre-heating/continuous press system.

Perhaps most significantly, the ultimate product is extremely stable in terms of moisture content and thus stiffness and strength.  Conventionally-made engineered wood products have 5% to 7% moisture content, and they will absorb additional moisture, bringing the final amount up to 11% or 12%.  However, Sunpine's LVL has an initial moisture content of 9% or 10%, so it will absorb less moisture from the environment.  Baby says, "Because of our low COV, we can mix fewer of the high-grade veneers with the lower-grades to meet the industry/customer strength standards, and thus we use fewer high-grade materials than our competitors to get the same quality.

The drawback to microwave is higher capital costs, although Baby says the payback is faster than with conventional systems.  Those capital costs include the expertise and knowledge that is involved in establishing the system and training the operators.  Tekle says, "You have to optimize the line and understand how the process works for a specific plant situation."  Without it, he says there will be "pain" in getting the system to work.

**Conclusion**

Microwave's commercial use in continuously-manufactured wide-billet LVL engineered wood goes back only to 1997 at the Sunpine plant, though the technology's use in the industry dates back to 1982.  Since 1997, however, the RFT/Dieffenbacher/EWES team has been involved in the construction of four more plants: two in the US and two in New Zealand.  All the plants manufacture LVL, but Harris is eager to expand the technology to the full spectrum of engineered wood products.  RFT is also looking into using µW as the primary curing method for engineered wood, rather than for pre-heating only.

Besides its use for manufacturing glulam, RF is also used for curing glue in the fingerjoints of I-joist flanges.  Tillett wants to see RF used for the entire I-joist assembly. In general, Tillett hopes to expand the use of RF well beyond Barkley's estimate of 10% penetration in the industry.  He says, "I am waiting for customers to come in with interesting inquiries" about ways to use RF in engineered wood.

Both RF and µW ensure a direct and rapid curing of glue, despite their very different methods of application.  They both have particular application to the thicker, longer products today's market desires, especially since most raw stock is too small to create these products and must be laminated or fingerjointed to do so.  In the coming years, conventional manufacturing processes may well yield completely to one or both of these high-tech methods.

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