FoMRHI Comm. 2043 **Jan Bouterse**

Making woodwind instruments

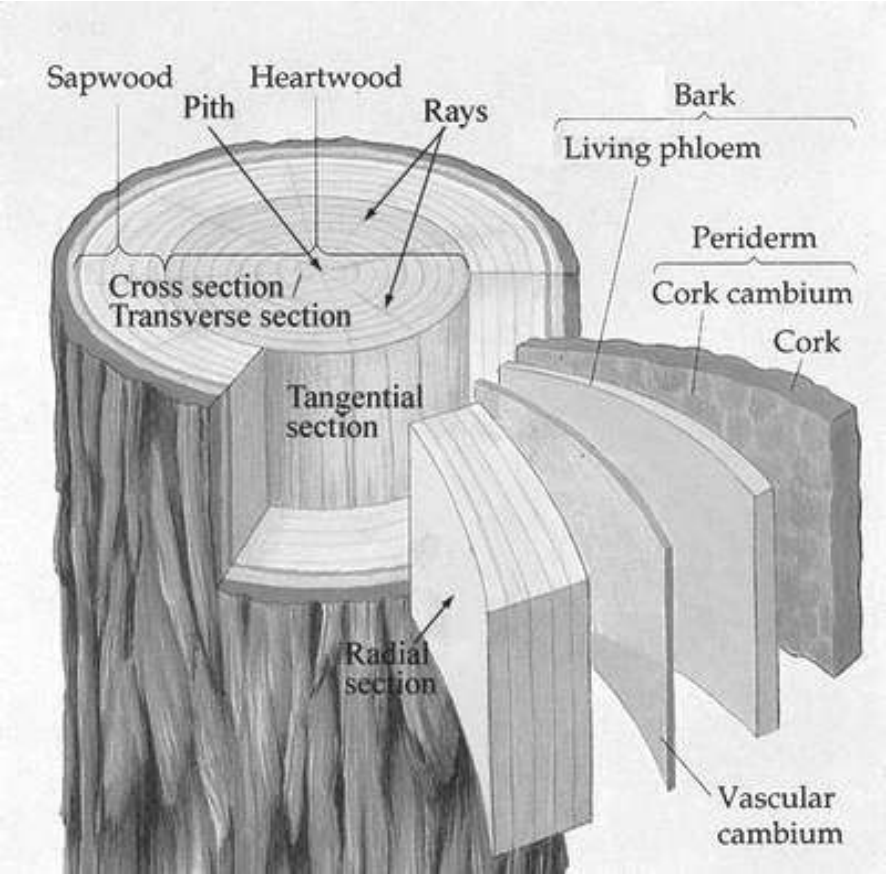
4- Wood for woodwind instruments - part 1: the properties of wood, making a choice

Introduction

Wood is a fantastic versatile material, fit for many purposes and generally easy to work. Important questions for makers of musical instruments are: what is the right species of wood for me, where can I buy it and how can I assess the quality.

I am sometimes asked by people how marvellous it must be for me to work with 'living material'; my answer was that I prefer very much wood that is as dry and stable as possible, and surely not alive. Of course, wood is a natural material: there is never a piece exactly the same. Another aspect: wood is not harmless; some species may have a bad effect on your health. In this article I tell about experiences with the woods I use myself, in combination with giving some practical and technical information from other sources.

There are many interesting facts about wood te be found in books and on internet sites. Basic is the site DoITPoMS from the University of Cambridge. On www.doitpoms. ac.uk /tlplib/wood/structure_wood_pt2.php you can see this diagram in colour:



Especially interesting is the wood-database (www.wood-database.com). I give here from that website the description of European boxwood, a species that was often used for historic woodwind instruments (and nowadays again for making copies). I have underlined the information which is most relevant for woodwind makers.

Boxwood (*Buxus sempervirens*)

- Common Name(s): Boxwood, Common Box, European Box
- Scientific Name: Buxus sempervirens
- Distribution: Europe, northwest Africa, and southwest Asia
- Tree Size: 10-25 ft (3-8 m) tall, 4-6 in (12-20 cm) trunk diameter
- Average Dried Weight: 61 lbs/ft3 (975 kg/m3)
- Specific Gravity (Basic, 12% MC): .68, .98
- Janka Hardness: 2,840 lbf (12,610 N)
- Modulus of Rupture: 20,960 lbf/in2 (144.5 MPa)
- Elastic Modulus: 2,494,000 lbf/in2 (17.20 GPa)
- Crushing Strength: 9,950 lbf/in2 (68.6 MPa)
- Shrinkage: Radial: 6.2%, Tangential: 9.8%, Volumetric: 15.8%, T/R Ratio: 1.6
- Color/Appearance: Color tends to be a light cream to yellow, which tends to darken slightly with prolonged exposure to light. Sapwood not distinct from heartwood.
- Grain/Texture: Boxwood has a fine, even texture with a natural luster. The grain tends to be straight or slightly irregular.
- Endgrain: Diffuse-porous; small pores, very numerous, exclusively solitary; growth rings distinct due to decrease in latewood pore frequency and color change; parenchyma not visible; narrow rays, normal spacing.
- Rot Resistance: Heartwood is rated as durable, though it can become stained with dark streaks due to fungal attack. Occasionally susceptible to insect attack.
- Workability: Boxwood tends to be somewhat difficult to work in flat dimensions, though it is superbly suited for turning. Tearout can occur on pieces with irregular grain during planing and other machining operations. Boxwood has a slight blunting effect on cutters.
- Odor: No characteristic odor.
- Allergies/Toxicity: Although severe reactions are quite uncommon, Boxwood has been reported as a sensitizer. Usually most common reactions simply include eye, skin, and respiratory irritation.
- Pricing/Availability: Usually only available in small quantities and sizes, Boxwood tends to be very expensive.
- Sustainability: This wood species is not listed in the CITES Appendices or on the IUCN Red List of Threatened Species.
- Common Uses: Boxwood is well-suited for carving and turning, and the tree's diminutive size restricts it to smaller projects. Some common uses for Boxwood include: carvings, chess pieces, musical instruments (flutes, recorders, woodwinds, etc.), rulers, handles, turned objects, and other small specialty items.

Comments: It's a shame that the term 'Boxwood' has become so convoluted and confused in modern times, as there seems to be one particular wood species that has historically been associated with the name Boxwood: Buxus sempervirens. It is this species that can be considered the original, genuine boxwood.

- Boxwood's ability to hold crisp details in carvings and lathe work, in combination with its color and silky-fine texture truly make it a classic.
- Other species in different genera tend to have similar appearances and working characteristics, (i.e., fine texture, hard, and heavy), and perhaps get marketed under the boxwood name, much like many woods are called by the mahogany name.
- Related species: None available.

A short explanation to the description

Technical terms are elucidated on the website (click on the word). Some examples:

- Specific gravity: this is according the explanation without a doubt the single most abused and vaguely used term in woodworking terminology. Technically, specific gravity is a measure of the ratio of a wood's density as compared to water. (So if a wood is of the same density as water, the specific gravity would be 1.00.) However, as with any density measurement for wood, it is greatly dependent upon the wood's moisture content: the more moisture the wood contains, the denser it will be. The chief problem arises is that there is no standardized way between woodworkers and botanists to express specific gravity: and there is no implicit or assumed values. At least with average dried weight, the moisture content is generally assumed to be at 12% unless otherwise noted.
- Janka Hardness, about which is said that this number is incredibly useful in directly determining how well a wood will withstand dents, dings, and wear, as well as indirectly predicting the difficulty in nailing, screwing, sanding, or sawing a given wood species. For reference, White Oak has a Janka hardness of 1,360 lbf (6,000 N), while the super-hard Lignum Vitae has a hardness of an astounding 4,500 lbf (20,000 N). On the lower end of the spectrum, Basswood has a hardness of around 410 lbf (1,800 N).
- About shrinkage: a basic measurement of shrinkage is the amount that the wood shrinks when going from its green to ovendry state. In other words, since wood in its green state is at its largest dimension, and ovendry represents its driest (and therefore smallest) volume, green to ovendry is a measurement of the maximum possible percentage of shrinkage; this is referred to as the wood's volumetric shrinkage. Wood is anisotropic, which means that it has different properties depending on the direction or orientation of the grain; that also applies to shrinkage when the wood is dried. Shrinking in tangential direction is always more pronounced than in radial direction; in comparison the shrinkage in length direction is very small. However: instrument parts which got crooked show that there is some difference in shrinking in length direction.

    The wood database gives for the shrinkage of boxwood: radial: 6.2%, tangential: 9.8%, but in a Dutch publication ('Houtsoortenvadamecum') I found values of 11% and 15%, which indicates (and that is also my experience) that the shrinkage of boxwood from green to overdry is bigger than of other wood species which are used in woodwinds making.

- Sustainability: Buxus sempervirens is found in several parts of Europe, bigger trees are more commonly found in countries around the Mediterranean. It is not on the IUCN Red List of threatened species, but the prices are now much more higher than they were 30 years ago. That is in indication that first quality of the wood has become more rare. Boxwood has one advantage: after cutting it can grow again to a new tree. And maybe, afte 100 years, you can cut it again.
- I am no so sure if boxwood from Asia is the same species as Buxus sempervirens. The genus Buxus contains approximately 112 to 116 species and belongs to the family of the Buxaceae (Boxwood Family, see http://en.hortipedia.com/wiki/Buxus_sempervirens). My first traverso (a copy after Scherer, made by Guido Klemisch) was made of boxwood from Thailand (or there about). On www.nytimes.com/1986/11/23/travel/shopper-s-world-japanese-combs-crafted-from-history.html is a story about wooden combs which are made of Japanese or Thai boxwood. No scientific names of the species are mentioned, but it is likely that both types of boxwood are varieties of Buxus microphylla.

Identifying wood
Identifying wood is sometimes straightforward, but often difficult. For instance the differences between ebony and African blackwood: I have seen a series samples in the xylotheque (= collection of wood samples) of the Wageningen University which show so much variation in colour (from completely black to dark brown) and texture (from very fine to moderately fine grain), that since then I am very cautious in describing the dark black woods of historical woodwinds: also because these instruments were as a rule severely polished and oiled, which makes identifying even more difficult. A magnifying glass doesn't help here to see the details in the wood. A microscope is needed for a secure identification; but then you must cut pieces from the wood, and that means an action of destruction, even when the slices - are very thin (which they have to be). See www.wood-database.com/wood -articles/the-truth- behind-wood-identification/ for an interesting essay about the difficulties of wood indentification.
Who is interested in wood, may join an organisation as the International Wood Collectors Society (www.woodcollectors.org. For Dutch readers: www.houtinfo.nl gives a database of wood species, and information how to use them.

Making a choice
There are world wide many - some sources mention over 100.000 - species of trees. It is therefore a bit difficult to make a choice for our job: making woodwind instruments. My advice for inexperienced makers: do not begin with experiments with rare on unusual woods, but look what other people do. Historical woodwinds are often made of (European) boxwood, maple (also called sycamore, often used for long instruments such as bass recorders and bassoons), fruit woods (plum, cherry, pear wood) or expensive tropical woods such as ebony or rosewood. In modern woodwinds there is a more variation, as you can find in the catalogues of recorder factories. You do not find these timbers in DIY-shops; you must go to traders (or websites) who sell exotic woods. In the Netherlands these firms are called 'fijnhouthandels', also traders in fine wood. In Germany: 'Feinholz' or 'Edelholz'.

Qualities and aspects which are important for instrument makers:
- acoustical properties of the wood, related to its density (specific weight, spacing of the growth rings)
- availability in relation with nature conservation (endangered species, CITES)
- availability in relation with size (length and diameter) of the logs and price
- weight of the wood
- quality of the logs: straight, twisted grain, free of knots and decay
- grain: fine or coarse, regular (straight), irregular (curly), with long or short fibres
- aspects of drying the wood (how long it takes, possibilities for speeding up drying)
- stability of the wood when it is exposed to moisture (condensation in the bore)
- health aspects (is the wood poisonous, irritating, bad smelling)
- reaction to the tools (some woods have silicious contents which make tools rapidly blunt)

Another advice: it is important to get really familiar with the wood of your choice. But that is often complicated, and you will often have the suprise of new experiences. Sometimes I struggle with a piece of wood (for instance boxwood or olive wood), there are irregegular spots, cutting is difficult and everything goes slowly. And other pieces of wood of the same species are a real feast: drilling, turning, cutting, it is all an easy and pleasant job. And these

differences in the behaviour are often unpredictable: the difficulties come as a surprise. That leads to the question: which pieces of wood makes the best instruments, the easy or the difficult ones? I don't know the answer!

Acoustical properties of wood

What makes the differences in acoustical behaviour between timbers used in woodwind instruments? First, we must consider that each instrument has essentially two parts: a generator for the production of the sound (vibrations of the air), and a resonator in which those vibrations are transformed to the desired pitch (by opening tone holes).

The generator for a traverso is the mouthhole, for reed instruments the reed, for recorders the sharp edged of the labium; but those items are actually the end point of a longer way: the creation of sound starts of course in the body of the player: mouth, lungs, diaphragma where the wood of the instrument doesn't play a role. But it does that surely for the resonator. It is in the bore of the instruments a matter of reflecting or adsorption of the harmonics of the tones, which is different for all types of wood. The properties of the surface of the wood play also an important role: for instance polishing the wood or impregnating or covering it with oils - some of them giving a soft, other a hard layer.

It should be easy to set up a research into the acoustical properties of various timbers. Make tubes in those timbers with the same internal and external dimensions, place a small loudspeaker to the entrance of a tube, generate a well-defined sound by that loudspeaker, and measure the sound spectrum at the other end of the tube. But I do not know about such research, maybe that I can find a laboratorium which will give it a chance.

For recorders, however, there is information on websites of some factories about what they believe is the sound of their instruments. I have collected the data on a selection of websites of Mollenhauer (Germany), Aafab (Netherland, with the brands Aura and Coolsma), Von Huene (USA) and Lazar (http://www.lazarsearlymusic.com).

Eureopean boxwood

Mollenhauer recorders: bright and rich in overtones.

Aafab: Boxwood is a very compact and heavy wood and is traditionally used for woodwind instruments. The sound of boxwood recorders is warm, clear and rich in overtones.

Von Huene: Genuine boxwood of this type is extremely fine grained, and carves beautifully. However, because it is extremely slow-growing (a tree large enough to use for instruments may be as much as 300-500 years old!), the wood is often full of knots, splits, cracks, and other imperfections. Boxwood is quite labor intensive; it is difficult to find a length large enough to make an entire instrument, so the head, center and foot are each turned from a different piece, which must be matched for grain and color. Blemishes are often not visible until the wood is turned, and a nearly finished piece must be discarded. The natural color of boxwood is pale yellow, but it is frequently stained darker colors. Early makers stained boxwood instruments to make them look more exotic and elegant, to help the different pieces of an instrument match better, or to disguise discoloration in the wood.

Lazar: boxwood recorders have an elegant tone

Castello boxwood

Mollenhauer recorders: a warm and bright sound.

Von Huene: Castello, Maracaibo and Zapatero boxwoods are varieties of South American or Asian origin, unrelated to true European boxwood. They are less dense and not so

fine-grained, but grow faster and straighter, making these woods far more economical to use for large-scale production.
Lazar: dense and firm, easy response.

Olive wood

Mollenhauer recorders: full, open tone.

Fruit woods

pear wood:

Mollenhauer: a warm sound with a strong fundamental.
Aafab: Pear is a medium heavy wood which like maple is impregnated with paraffin. That makes it more resistant against moisture and makes the sound more full. The sound of pear wood recorders is soft with a strong fundamental.

plum wood:

Mollenhauer: earthy sound, smooth structure.
Lazar: firm and resonant sound.

Maple

Mollenhauer: soft and light sound.
Aafab: maple is impregnated with paraffin; the sound: soft with a strong fundamental
Von Huene: ice for copies of Renaissance recorders because surviving original instruments were made of maple or similar woods. It is available in very large, consistent pieces, particularly important for Renaissance instruments which frequently require very large recorders to be made in only one or two pieces. It is also lighter in weight and for this reason, it is also used for Baroque and modern tenor & bass recorders. Maple can also be very decorative when a piece has curly, 'flamed' or otherwise figured grain. It is also used for many inexpensive recorders, and is porous enough that it is sometimes impregnated with wax under pressure to help protect the wood from absorbing too much moisture. Its natural color is very light, but it is often stained to bring out the beauty of the grain. We use American hard maple which has a sweet, warm tone and blends well with other instruments. German makers sometimes use European sycamore (also called sycamore maple), particularly for Renaissance recorders.

Palisander, rosewood

Mollenhauer: robust, well-balanced and forceful sound.
Aafab: clear and rich in overtones; palisander gives sometimes allergic reactions.
Von Huene: 'Rosewood' is a generic term for a variety of woods in the Dalbergia family, including palisander, kingwood, tulipwood, and many others (so-called because when these woods are cut, they emit a faint scent of roses). Rosewoods have very colorful, high-contrast grain, striking in appearance, and ranging in color from orange through reds and purples to deep brown. We select only the finest woods for their exceptional grain and beauty. The tone of rosewood recorders is typically reedy and rich in overtones. But there are so many varieties of 'rosewood', terminology can vary. For example, Moeck produces recorders in both palisander and tulipwood, but designate the latter simply as 'rosewood', which can sometimes cause confusion.
Lazar: vigorous tone, rich with overtones.

Tulipwood

Mollenhauer: full tone with a strong fundamental.
Lazar: easy response, rich sound.

Ebony

Von Huene: African ebony is a very hard, dense wood, deep brown to black in color, a favorite of makers looking to produce outstanding visual pieces. Its density gives it a

bright, bold, and powerful tone, which many players favor for concerto instruments where volume is a concern.

African blackwood - grenadilla

Mollenhauer: intense and elegant tone.

Aafab: a clear sound, rich with overtones, elegant.

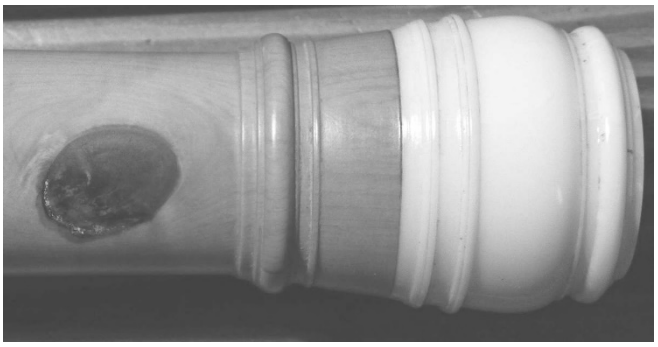
Von Huene: Grenadilla is a beautiful, dark wood that resembles ebony but may have a bit more brown in the grain. Extremely tough and durable, grenadilla produces a tone that is bright, clear, and penetrating; many of our customers favor grenadilla instruments for solo and concerto work.

Lazar: precise and elegant tone.

Comment: I suppose that a 'warm sound' means that the fundamental is strong, and that a 'bright sound' is rich with overtones. But what exactly is for instance a 'robust sound' or an 'elegant tone'? My experience: hard woods give a loud sound, but you will also hear some of the noises louder. And heavy woods als grenadilla need more time to warm up, to avoid clogging by condensation of the windway.

A summary of my own experiences

I have used European boxwood with good results for recorders, traversos and oboes. But as Von Huene said: boxwood is quite labor intensive, and you must solve many smaller or greater problems. The black spot on the head of an alto recorder (see photo) was not visible at first when the wood was still thicker. On the lathe it became bigger and bigger, there was also leakage of air.



I solved the problem by impregnating and filling up all crevices with glue, but that was not enough. I made the socket at the right much longer (to just after the knot) and glued in a new ring (lining) of boxwood in the bore. It is now one of my finest instruments.

I have also made some recorders and traversos from ebony, but I prefer for recorders palisander, for instacne Santos palisander which I onse bought as 'iron wood'. The problem: some people getting really ill when they make or even play these instruments. And it is also difficult to find pieces of the same colour and quality of this wood. The same applies to olive wood - which gives a very refined sound to recorders - and there is something else: I do not know how long these instruments will last.

For my workshops I have also used pear (with has a rather dull appearance), cherry and plum wood (much nicer). Cherry and plum are both from the genus Prunus, and again there is a lot of variation in quality (weight, grain) within these timbers. You need always to oil the instru-ments heavily to get a nice sound, or - what I discovered with some pieces of pear wood - to get a sound at all.

Other woods I have used: laburnum (from a tree in a garden nearby), which has a beautiful dark colour, but workability is not so easy and the wood is poisonous or irritating, at least for some people (I myself had no problems). Bubinga is a dark red wood from Africa; it is used by some recorder factories and long ago I bought quite a lot of this timber. But the grain was rather irregular and it was difficult to get a smooth surface of the windway roof and labium.

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Making woodwind instruments

4- Wood for woodwind instruments - part 2: buying, drying and new developments

Buying and selection of timbers

Most timbers for woodwind instruments can only bought at specialist suppliers, their name and addresses you can find on internet. Please remember that 'tone woods' are woods for string instruments. In English language the term 'soft wood' is used for the wood of coniferous trees, but in other languages (Dutch) it is a term for every species of wood which has a soft texture. Some coniferous trees produce a harder quality of wood than deciduous trees (trees with leaves); I know of an instrument maker who made a picollo traverso of thuja wood.

Buying wood on internet is a matter of trust: hoping that you get the right species, the right dimensions, a good quality. But buying in a shop is also not easy. A general rule is that small (narrow) growth rings indicate that the tree has grown slowly, and that the wood is harder. In the case of boxwood you can select the most straight stems, but as a rule you can't easily see the spacing of the growth rings.

> Some violin makers go themselves to the forests to select trees, knock them with a hammer and listen to the resonance. A Swiss dealer of tonewoods told me that such way of selecting has no much sense. Only after felling the tree and cutting the logs into quartered sections, you can tell more about the quality, he said. Woods for string instruments is sold in various quality classes, from A, AA, AAA to Master quality (see www.tonewood.ch for more information). I have never seen such qualifications for woodwind timbers, but the quality of what you can buy does vary rather much. But you must judge those qualities yourself, and that is not an easy job, especially when you are buying logs (sections of stems) which are not sawn in parts.

Strong stories?

There are many strong stories about wood. Sometimes they might be true, such as that trees which grow on water veins are stressed and develop twisted grain. Another story is that wood which is cut at the right moment within a moon cycle (of course in one of the winter months) is more stable and is better for making musical instruments. The Swiss company mentioned above has carried out in cooperation with a research institute a study to determine whether variations in wood characteristics are connected with lunar cycles. Wood (mainly spruce, which is of course not a species which is used for woodwind instruments) that was cut during the weaning phase of the moon, showed less variations in moisture content. That means: in the drying process it lost less weight, but when exposed to wet conditions, it also absorbed less moisture. As result: this wood is - or should be - more stable, it doesn't shrink and expand so much when during the seasons and in changing conditions. We might assume that the same applies to woods used in wind instruments.

The Austrian woodwind maker Rudolph Tutz once told me a very strong story: elm wood, cut at the right moment in the moon cycle, was freshly used for a floor in a house and didn't shrink at all in the following years. But fresh (thus wet) wood is rarely used for woodwind instruments. We know that it is done for the Norwagian *seljefløyte*, a foulk recorder, made of willow wood. This is however rather simple instrument which has not a long lifespan.

Measuring the moisture content of wood

The important question: is the wood that you just bought dry or stable enough for its destination: to become part of your instrument? There is no simple answer. Several timbers are artificially dried before being sold, but even then you can't be sure whether it can be used directly.

Measuring moisture content (MC) of wood is a science in itself. The website www.ces.ncsu.edu/nreos/wood/wpn/methods_moisture.htm gives a well-organized survey of how it can be done.

- The traditional - but not so practical - way to measure the MC is to take a sample of the wood and dry it in controlled conditions in a ventilated oven at 100 to 105° C until it the weight is constant. The loss of weight gives you exactly what the MC was before drying.
- Electric moisture meters allow the user to rapidly and accurately estimate wood MC's less than 30%. Most hand held moisture meters are typically either resistance (pin type) or dielectric (flat plate) meters. In the past, meter readings needed to be corrected for species and temperature by hand using printed tables. Today, commercially available state-of-the-art moisture meters have species and temperature corrections built into the digital circuitry. Both types of meters offer the same accuracy over about the same range of MC's. None of these meters provide accurate readings above 25 to 30% MC.
- Resistance moisture meters uses pin type electrodes that penetrate the wood up to depths of 2½ inches. That causes holes in the wood, and apart from that, you can only use such pins if softer types of woods which are generally no use for woodwind makers.
- Dielectric moisture meters use surface contact, flat plate electrodes that do not penetrate the wood. The depth of penetration by the measuring field ranges from 0.5" to 1.0" depending on the model. In situations where the field penetration is greater than the thickness of the wood, care should be taken as the reading will be affected by the material beneath. Dielectric meters read the average MC of the zone penetrated by the electric field. Similar to resistance meters, the accuracy of dielectric meters in measuring average MC is + 1% moisture content. The readings are reportedly most influenced by the wood nearest the electrode, and are consequently more reliable on wood with a fairly uniform MC than on wood with substantial moisture gradients.

  Corrections for wood species must be performed due to density differences between species. It maybe necessary compare meter readings from representative samples with the MC determined by ovendrying.

With pins that penetrate the lumber, resistance meters leave holes in the wood. Dielectric meters use surface contact electrodes that are non-invasive and leave no marks. But how usefull are these meters on small pieces of wood, such as blanks that we use for instrument parts?

Storage and drying of wood

What can you do to lay up the wood, and improve the quality? At first: the website 'wood database' (for instance the article by Eric Meier on www.wood- database.com/wood-articles/drying-wood-at-home/) gives detailed information about almost every aspect of using and drying wood. There is no need to repeat here all instructions you can find there; I concentrate on my own experiences with wood for making woodwind instruments.

Always remember: the process of drying of wood has two main components: a- the water that escapes from the wood to the surrounding air, and b- the transport of the water inside the wood to the surface of the wood. These two components must be in balance. When a- is going too fast, the wood will crack on its surface. When b- is going too fast (which happens

with some ways of artificial drying), internal cracks may occur in the wood, which are even nastier because you can’t see them until you are start working with the wood.

Freshly cut wood and water storage

In the past years, I have got several deleveries of wood by various people: sometimes small pieces, but also rather large sections of tree stems: boxwood, cherry and plum, laburnum (nice wood, but poisonous), ash (for tool handles) and some other obscure species. These timbers are generally very wet, the logs contain a large amount of water which often constitutes up to 50% of the wood's weight. Most of this water will evaporate when the wood is placed in dryer conditions, resulting in an equilibrium with the relative humidity of the surrounding air. But that takes some time, depending on the thickness of the logs and the type of wood. The best way is gradually seasoning the wood, starting outside in a covered (but not damp) place where the logs are stacked up so that the wind can blow free through the pile. But at first it is better to remove the bark and cut (or saw) the fresh wood in smaller parts (for instance quartering). And it is important to remember that moisture escapes from wood much faster on the ends than through other surfaces, causing tensions which will result in cracks. Sealing the end grain forces the moisture to exit in a slower, more uniform manner and reduce the developing of cracks. I use simple white wood glue for sealing the ends, other possibilities are water-based wax emulsions, latex paint or liquid paraffin.

I must make here a remark about water storage of wood, which is submersing freshly cut tree trunks in ponds or basins with streaming water. It is a traditional method of protecting wood against decay (for instance by fungi or insects), especially in situations where there is no time to saw the trunks into smaller sections to be dried in the air (see below). But this system of water storage can also improve the quality of the wood, reducing the tensions in the wood (which are the result of the felling of the trees) and at least for some species (e.g. fruit woods): water soluble carbohydrates, which are one of the the causes of fungal decay, are rinsed out. But I could hardly find any useful information in English language on internet about water storage. Is this tradition dying out? As a result I can give here no advice what to do with wood logs.

After a year in the pile outside on a sheltered place, fruit wood (and similar) species can be moved to your workshop, garage or other dry and preferably non-heated room. It is good to cut or saw the logs (again) into smaller (square) pieces and remove the sapwood.

> **Important:** you must always saw the wood logs in sections which are oversized, longer (and thicker) than the intended instrument parts in which they will be transformed. When the wood is sufficiently dried, I remove at both ends of the log one centimeter (or about). This because the chance that there is still some tension at the ends, or there are tiny hair cracks which are hardly visible but might give real problems later on. And after this operation, there must be still some overlength left, as we need some margin when drilling and turning the wood into instrument parts. Do also not cut the logs in pieces which are thin in relation to the length, since there is a chance that they will distort during the drying process.

Photo: I saw this little rack, just under the ceiling in the workshop of an amateur organ maker: on this warm spot he keeps the wood for the keyboards of his instruments.

Exotic woods

Most exotic (e.g. tropical) woods which you can by in Europe are dry enough to be stored inside your house, in a non-heated room. If it is not done already, you must seal the ends to avoid cracks. Before using the wood, it is often better to saw it in smaller pieces and move those into your workshop. Remember that in the winter season when it is freezing, the humidity of the air in your house can be very low. That can result in cracks or thinner pieces of wood which might deform.

Boxwood

Boxwood must be seasoned slowly, especially when you buy it as stems. Put these for some years in a cool cellar to avoid the forming of cracks.
A warning: fungi may attack the wood when it is stored in too wet conditions. It causes dark spots in the wood, which make it not useless, but might give health problems. I myself am, however, not too afraid of cracks. One long crack in the wood means that the wood beside the crack is free of tensions (or at least I hope so). The stem on the photo has a maximum diameter of about 20 cm, which is for boxwood very thick. The stem in the background has a strongly twisted crack, which makes is much more difficult to saw it in smaller pieces for parts of woodwind instruments. Both stems are now for approximately 30 years in my workshop, which is dry, but has no heating. It is really necessary to saw the wood in smaller pieces and move them gradually in warmer places, as told above with the other woods. The pieces must have a moisture content of 12% or less.

Boxwood in the microwave oven

The general advice for boxwood is also: do the drying process slowly. But I have done some experiments with drying pieces of boxwood in a microwave oven, see FoMRHI-Q 40 (1985), p. 74/75. 'The microwave way: drying boxwood fast and easy' (Comm. 641). I have no new information, apart from the fact that I have obtained good results with this method. The essence of the microwave radiation is that it triggers the water molecules throughout the whole body of a piece of wood, which starts the process of transport of the water to the surface of the wood, where it escapes into the air. What I do is taking a few pieces of boxwood (for instance 1000 gram), measure the weight (with an accuracy of 1 gram), set the oven on 50% for 15 minutes. Please remember that all microwave ovens have only one energy level (100%): reducing the energy by putting the control button on 50% means actually that the oven is only working half of the time, for instance 20 seconds on and 20 seconds off (etc.). The wood becomes (very) warm, and when I see that it looses some weight (for instance 2 to 5 gram), I set the oven on a lower level (40 or even 30%) and measure the weight every 5 minutes, until the wood has lost 5% of its weight. It is important to seal both ends of the wood, which I do with white glue. Another advice: cut after drying 1 centimeter off both ends, because those are the places where the wood might have developed some tensions or micro cracks.

I had rather good results in drying boxwood in this way, the wood became much more stable and recorders and flutes didn't crook or shrink. I checked thin slices of wood with a microscope and couldn't detect any differences with boxwood that was dried in the natural way. However, some people say that the wood becomes a bit brittle in the microwave oven. My own experience is also that when turning the wood on a lathe, you might not get quite such a beautiful shaving as with untreated wood.

Microwave drying failed completely with olive wood: that got internal cracks, caused by a very slow water transport inside the wood. I did another observation in the same line: a test with submersing two pieces of boxwood and olive wood in linseed oil revealed that the boxwood piece had soaked a lot of oil and became about 10% heavier; but the olive wood didn't absorb the oil at all and stayed at the same weight. Impregnating or sealing wood with oil is the subject of many discussions between woodwind makers and players. It is, however, difficult to find useful information; I will give my own experiences in an other article.

New developments in drying and modifying wood

The normal way to season wood is in climate chambers, where temperature and air humidity exactly can be regulated. The time that the wood must be in these chambers depends on the species and the thickness of the timbers. Some woods are treated with steam before they are dried; I know about steamed pear wood and walnut. Steaming is done for improving the stability and the colour of the wood. It is more or less the same process as watering of wood logs, which I mentioned before.

There are recently new developments in drying and modifying wood. On.wikipedia (under Thermally_modified_wood) you can read about it. There are chemical techniques, such as impregnating wood with acids (accoya, kebony) and thermal treatments such as the Plato process (invented by Shell, but now in an independent factory). The durability of the wood is improved, it becomes harder and maybe that the qualities for some type of musical instruments will we better as well. Many years ago, the Plato-laboratorium did some test for me with samples of maple and Florida cedar. But maple didn't react well on the treatment, there was a lot of distortion. And for Florida cedar (for the blocks of the recorder) it was not

so useful. Heat treatment may give also a bad smell to the wood, and that is not preferable for a block. See www.platowood.com/wp-content/uploads/2015/08/. But maybe there will be new developments, I try to keep up to date. See The-Platowood-Process.pdf for more information about this interesting process.

An excursion to string instruments: torrefied wood and moon wood

Makers of string instruments use sometimes so-called torrefied wood which is heat-treated in an oxygen-free kiln (more or less similar to the Plato process), making it highly resonant and extremely stable. With the clear tone and warm color of well-aged vintage tonewood, it sounds and looks like wood that's been broken in for years. See for instance www.premier guitar.com/articles/21444-acoustic-soundboard-torrefied- woodsdont-be-afraid for more information about this articificial ageing of wood.

On the aforementioned website www.tonewood.ch I found a reaction of a Swiss violin builder who clearly had another approach: *Dendrochronological tests on violins from the Cremona school have shown that often very young wood* [I suppose: wood that was recently cut and had not been dried for a long period - Jan B.] *was used for the tops. Based on this scientific results I undertook to make a top from one-year old 'moon wood', meaning that the specific spruce was felled at the 'right' moment. The wood proved very easy to work. I would say that the resulting violin is an exceptional piece, striking by its very clear, brilliant and warm sound. It is remarkable that I only needed to adjust this violin once, which I ascribe to the stability of the 'moon wood'*. I have one remark to this story: the combination in the sound of 'very clear', 'brilliant' and 'warm', how must I see that? Which harmonics do play a role here?

Lignostone

I am always looking for alternatives for tropical hardwoods, fearing that several of those timbers which are commonly used for woodwind instruments will become extinct in the next decades. I have made some instruments in artificial ivory, but that is not an easy stuff to process and it has - like real ivory - some disadvantages.

It is quite some years ago that I found 'lignostone'. That is not petrified wood (which is not used for musical instruments), but a wood product, made in a factory in the Netherlands. It is a sheet material that is composed from layers of beach veneer. The layers are pressed and glued together with a resin under high pressure and temperature. Lignostone is used for making wooden hammers, but also because its good electrical insulation, low thermal conductivity and low water absorption as structural insulation in electrical apparatus such as transformer applications, and more recently also for bullet proof solutions, for instance in doors of buildings.

I have made a recorder and a traverso from lignostone. It seemd to be a perfect material, the specific weight was just above 1 (similar to grenadille), the colour was a beautiful dark brown and the layers of the wood were hardly visible as such and looked like natural growth rings; you could order the stuff in all required dimensions and it was ready to use. There was one disadvantage: the resin they used was not waterproof and the instruments got cracks. I received then a better quality, but that made my tools in a short time very blunt. The Dutch recorder company Aafab (Aura and Coolsma) have made in the past some series of instruments in lignostone, as far as I know with good results; maybe that I must try to do another test. But I must also say: it is much more a joy to work with natural wood, despite it has sometimes its imperfections.