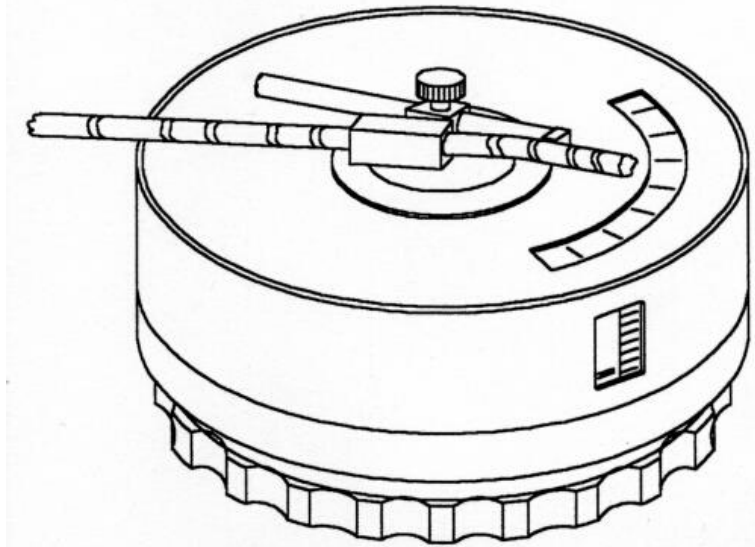


FRACTOMETER I



- measures the bending fracture strength of cores removed from the tree with an increment borer
- allows the assessment of decayed wood by measuring the stiffness and fracture strength
- brown rot is indicated by small bending angles and low fracture strength
- at early stages of decay lignin destruction is indicated by large bending angles and a rather normal fracture strength (some types of whit rot)

Manufacturer:

IML-Instrumenta Mechanik Labor System GmbH

Parkstraße 33 . 69168 Wiesloch

Germany

Phone: +49 6222 6797-0

Fax: +49 6222 6797-10

Website: www.iml.de

E-mail: info@iml.de

licensed by:

Nuclear Research Center Karlsruhe

Prof. Dr. Claus Mattheck

A GUIDE TO FRACTOMETER TREE ASSESSMENT

C. Mattheck (1), H. Breloer (2), K. Bethge (1)

(1) Karlsruhe Nuclear Research Center
Institute for Material Research II
P.O. Box 3640
D- 76021 Karlsruhe

(2) Tree Consultant Office
Nordring 11
D- 48480 Spelle

Abstract

A newly developed field testing device, the FRACTOMETER I is presented. By testing a cylindrical increment core, removed by an increment borer, the FRACTOMETER I enables the user to determine radial bending fracture strength and stiffness values for safety assessment of individual trees.

Introduction

In the past decades a number of good reference books were published which list the stiffness and strength properties of dry and green wood [2, 3, 12]. These data allow one to compare different kinds of wood from a mechanical view point and make an appropriate choice for the technical use in each individual case. In [1] it was shown by Dr. Klaus Bethge et al. that these ideal values can be reduced down to 20% by the presence of knots.

Besides, anyone who has ever taken a core from a decayed stem knows that, depending on the type of fungus, one finds a stiff- brittle or a soft- ductile wood property. Troll [11] has compared wood to steel reinforced concrete (Fig. 1): The strong and tough but flexible cellulose is equivalent to the steel and the stiff but rather brittle lignin can be compared with the concrete.

INSTRUCTIONS FOR USE: FRACTOMETER I

Early stages of brown rot destroy preferably the cellulose in an global and very non localized manner which resembles steel corrosion. This may reduce the strength very drastically without significant losses in stiffness or weight [4, 14]. Unexpected brittle fracture with crackled fracture areas frequently occurs under these circumstances. On the other hand, some white rots which destroy preferably lignin at the early stages of decay may lead to reduced stiffness which must not necessarily be accompanied by a decrease in strength. The wood becomes soft but remains quite though. This is comparable to concrete removal which leaves the though steel rods.

In the assessment of tree safety by use of the VTA method [9, 10] the mechanical design, i.e. the shape of the tree, is first checked visually. If symptoms of internal defects (repair growth or local bark stretching) are detected a closer inspection of trees near public places is required by law in Germany [9]. The tree can fail due to a bad mechanical design, but also a well- shaped tree which is not hollow at all or does not show cracks may easily break if the strength of the wood is decreased, for example due to decay. Even trees of the same species which seem healthy and grow on one site, may vary by a factor of 2 to 4 in their breaking strength without visible differences between the increment cores removed. Therefore, the technical reference books for wood properties have only a very limited value for the assessment of an individual tree. The tree under consideration is quite indifferent to the average stiffness and strength values of its colleagues, and is often damaged by fungi, or insects who do their best to reduce the mechanical wood quality further.

Here, the only way out seems to be the measurement of the wood quality in terms of the strength of just this individual tree. Care must be taken not injured the tree more than is necessary.

For this purpose the FRACTOMETER I [7] was developed at the Karlsruhe Nuclear Research Center. It was gratefully accepted by the community of tree experts who are using it especially to assess the risk of hazardous trees. The present paper gives an intermediate report of field experiences to make the range of applications available to interested readers.

The FRACTOMETER – its uses and options

The FRACTOMETER I is a pocket- size wood testing machine. It bends increasingly a cylindrical sample (core taken by use of an increment borer). Looking at bending angle and load, one can determine both the stiffness and the strength. Fig. 2 is an exploded view of the use and inner design of the FRACTOMETER I.

Current state of data

The results of recent field studies are now available in an updated reference table with FRACTOMETER I values of most European soft and hard woods. The table in Fig. 3 shows the enormous range of stiffness and strength values even within the same species.

INSTRUCTIONS FOR USE: FRACTOMETER I

This again confirms the extremely limited information available from technical reference books for the individual tree. The measurements in the table were made positioning the wooden core as shown in Fig. 4. So the almost- shaped wooden rays are bent in the direction of their highest stiffness (Fig. 4) as done by wind loading. If one rotated the core sample by 90° , this load case would be closely related to twisting of the overall tree stem but not to wind bending. The increment core would be loaded then as shown in Fig. 5, and the individual rays would be bent in the direction of the minimum stiffness. Smaller fracture loads and less stiffness are often measured in this way.

Decay detection by use of the FRACTOMETER I

Naturally, the FRACTOMETER I does not allow one to determine the name of fungi species inside the tree. It is an instrument which assesses the damage caused by fungi under field conditions. The two basic wood destruction patterns were already shown in Fig. 1. It is explained in Fig. 6 how the FRACTOMETER I results and wood properties in their more or less fungi- affected state are related to each other. What does large and small FRACTOMETER I value mean for each of the tree species listed in the table in Fig. 3. The answer is found regarding the two examples given below.

- 1. European oak:** FRACTOMETER bending moment at breakage = 115
bending angle at breakage = 37°

Diagnosis: Selective lignin destruction, lots of cellulose fibres still intact, possibly subsequent ductile fracture, secondary thickening (symptom formation) near the decayed spot to be expected (white rot).

- 2. European oak:** FRACTOMETER bending moment at breakage = 31
bending angle at breakage = 12°

Diagnosis: Selective cellulose destruction, much lignin intact yet, danger of brittle fracture (like a biscuit), symptom formation not necessarily to be expected (for example: early stage of brown rot).

Because of the limited symptom formation and the sudden type of brittle failure the second oak is more dangerous than the though- soft oak suffering from white rot in example 1.

INSTRUCTIONS FOR USE: FRACTOMETER I

FRACTOMETER I diagnosis and related decisions

Not all of the trees have a maximum FRACTOMETER I value (high strength) and minimum bending angle. Even in the healthy state birch and lime trees have quite a high bending angles above 20° before ductile breakage starts. On the other hand, the short- fibre beech wood often breaks very brittle at a bending angle of 13° . The following check list should help to make reasonable decisions for sufficient safety related to the special location of the tree.

High strength (large FRACTOMETER values) is required when:

- The tree is slanted and has a heavy crown
- the neighboring trees were felled or heavily thinned and the tree under consideration was not pruned
- the tree has weak spots (cracks, hollows, parts of the cross- section are missing, open wounds...etc.)
- the remaining wall thickness (remaining healthy wood of the hollow stem) of non- pruned hollow trees is close to the critical value of 30% of the radius [9, 10, 13].
- trees are located in public places

Furthermore:

The lower side of slanted broadleaved trees should have more lignin (small FRACTOMETER angles) and the upper side more cellulose (large FRACTOMETER angles), respectively.

A somewhat lower strength is allowed when:

- the tree has a drastically reduced sail area due to previous pruning
- the tree is located in places without much public traffic (German law)
- the local wind speeds are reduced by new buildings or faster growing trees which protect the tree from the wind loading. But note that changes in the wind direction may become dangerous even for healthy trees.

INSTRUCTIONS FOR USE: FRACTOMETER I

Final remarks

The authors have used the FRACTOMETER I for assessment of some hundred trees and obtained very satisfactory results. The device allows one to rapidly assess the radial distribution of strength and stiffness at the spot where the core was removed. This also allows one to determine the remaining wall thickness of hollow trees or of trees with decayed cores. Furthermore, information is obtained under field conditions about **how** the fungi have affected the mechanical properties of the wood. In this way, the potential failure mode (sudden brittle fracture or more predictive ductile fracture) can be predicted as a function of selective cellulose or lignin destruction.

Also after tree failure the FRACTOMETER I can help to assess the predictability of that accident and allows in this way to explain questions of reliability. Note that dry wood has a 2 to 4 times higher strength than green wood, so fast consideration will give best evidence under these circumstances. In no way the FRACTOMETER I (as all other methods for wood evaluation!) is a substitute for dendrological knowledge and understanding of the body language of trees [5, 6].

However, the FRACTOMETER I completes the visual assessment of trees by more quantitative evaluations which may definitely confirm or defuse existing concern. On the other hand, a careless pure mechanical testing procedure can easily and in a disaster. The authors therefore always strictly recommend to look at the tree as a system but not at the increment borer core only. You have to evaluate a tree but not a laboratory sample! Compare the defective tree to an equivalent healthy tree of similar size and shape and make your decision. Details of VTA (Visual Tree Assessment) are given in [10].

Always keep in your mind that also the healthy tree can break under tough circumstances. This natural failure rate is the price nature has to pay for the lightweight design which makes the survival of species so effective and energy- saving. The absolutely safe tree will never exist as our own bones may also break without previous defect, for example during physical exercise. Don't require trees to be safer than your own skeleton!

INSTRUCTIONS FOR USE: FRACTOMETER I

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INSTRUCTIONS FOR USE: FRACTOMETER I

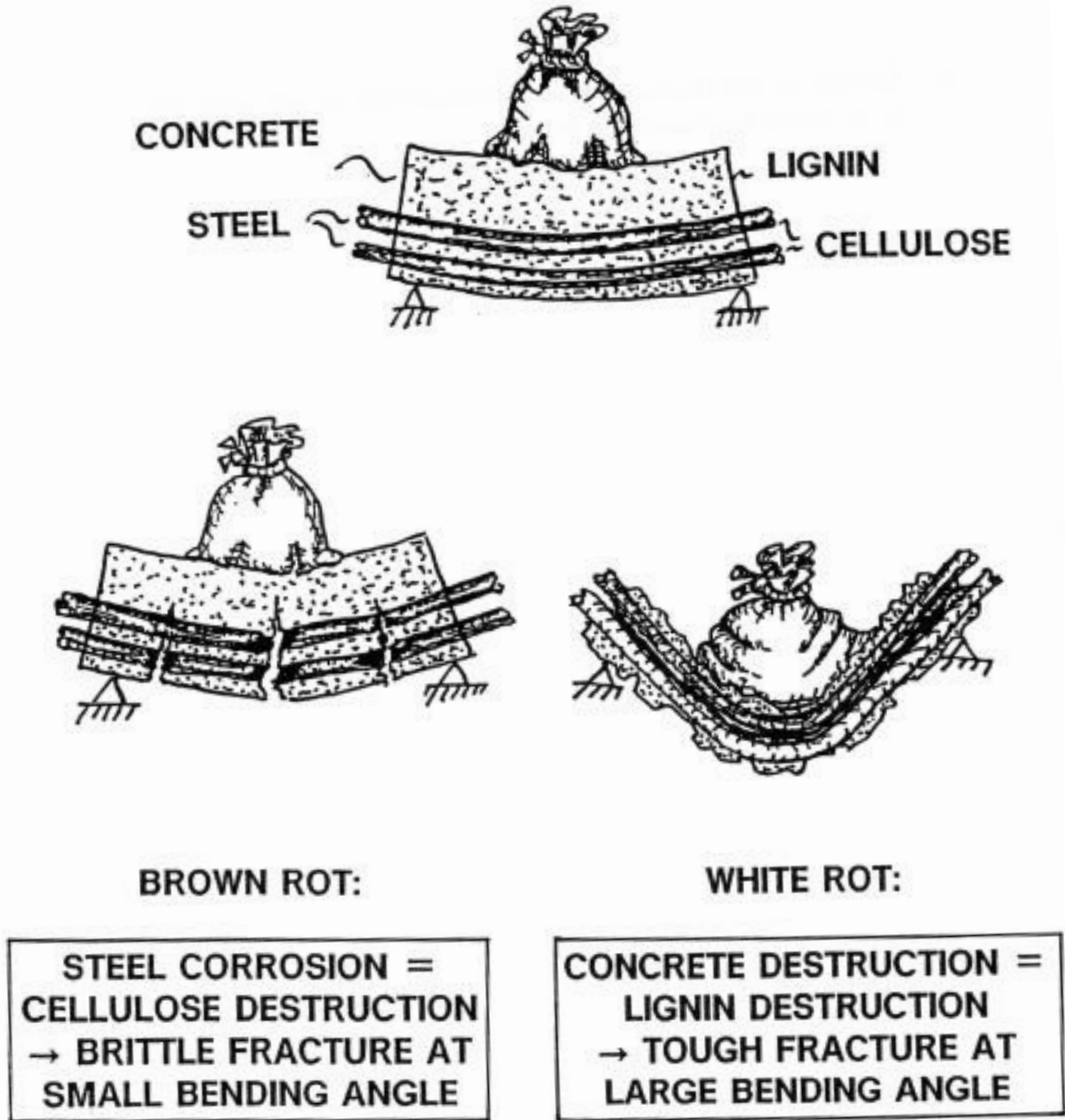


Fig. 1: Selective cellulose destruction (left) leads to brittle fracture mode. Selective lignin destruction (right) leads to a ductile- soft failure mode.

INSTRUCTIONS FOR USE: FRACTOMETER I

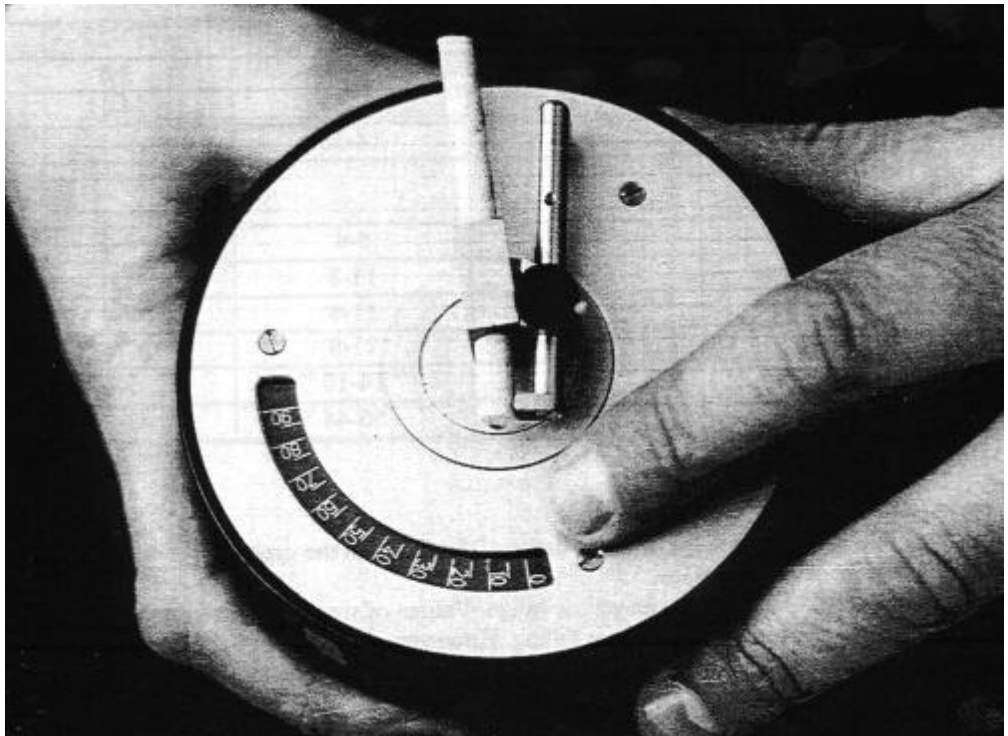
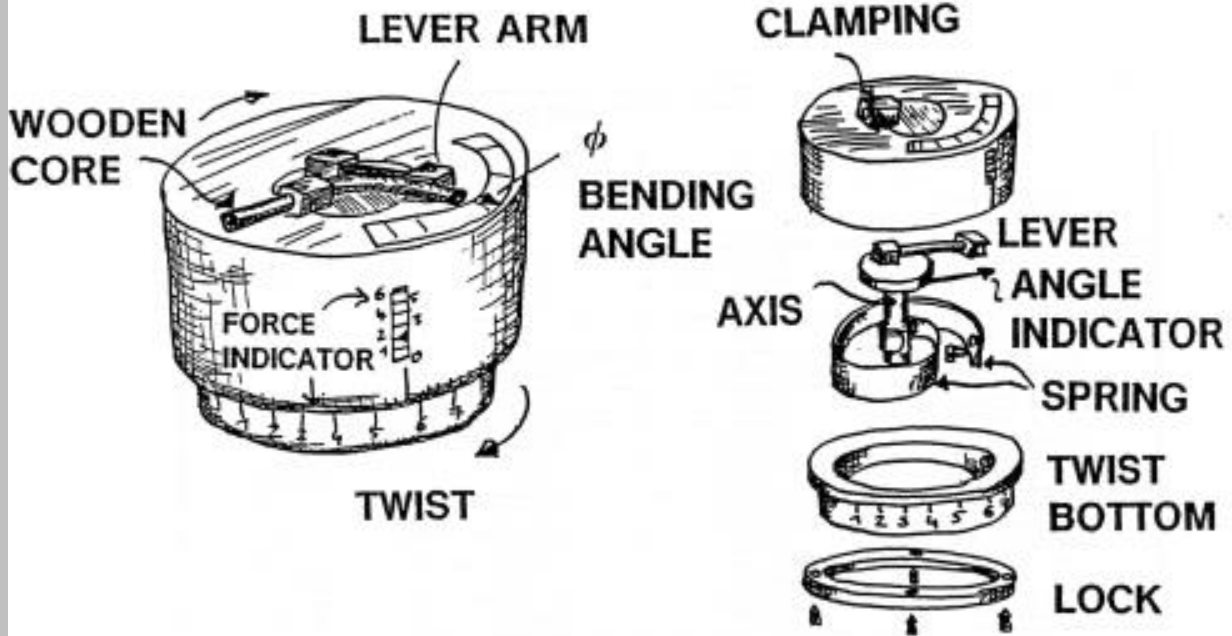


Fig. 2: The FRACTOMETER- a pocket- size wood testing machine.

INSTRUCTIONS FOR USE: FRACTOMETER I

Species	Fracture Moment in FRACTOMETER Units		
	Green	Yellow	Red
Hardwoods			
Ash	80- 59	58- 38	37- 18
Birch	40- 30	29- 20	19- 10
Black alder	50- 38	37- 25	24- 12
Black locust	120- 89	88- 58	57- 27
Black poplar	20- 15	14- 10	9- 5
Copper beech	120- 89	88- 58	57- 27
Elm	110- 82	81- 54	53- 26
Horn beam	120- 89	88- 58	57- 27
Horse chestnut	70- 52	51- 34	33- 16
Lime	60- 46	45- 30	29- 14
Maple	120- 89	88- 58	57- 27
Oak	120- 89	88- 58	57- 27
Pine poplar	20- 15	14- 10	9- 5
Plane	120- 89	88- 58	57- 27
Red beech	120- 89	88- 58	57- 27
Silver poplar	20- 15	14- 10	9- 5
Sweet chestnut	50- 38	37- 25	24- 12
Willow	20- 15	14- 10	9- 5
Softwoods			
Douglas fir	7- 6	5- 4	3- 2
Fir	15- 12	11- 8	7- 4
Larch	15- 12	11- 8	7- 4
Pine	15- 12	11- 8	7- 4
Spruce	20- 15	14- 10	9- 5
Yew- tree	90- 67	66- 44	43- 21

Healthy wood near decayed areas or other defects should be in the green range, as well as the values of wood from slanting trees. Heavily pruned trees should lie in the yellow range. Values of wood in the red range are critical and require drastically reduced crowns or felling. However, a fixed use of the table is dangerous. It is important to look at the tree as a system and not at the increment borer core only.

INSTRUCTIONS FOR USE: FRACTOMETER I

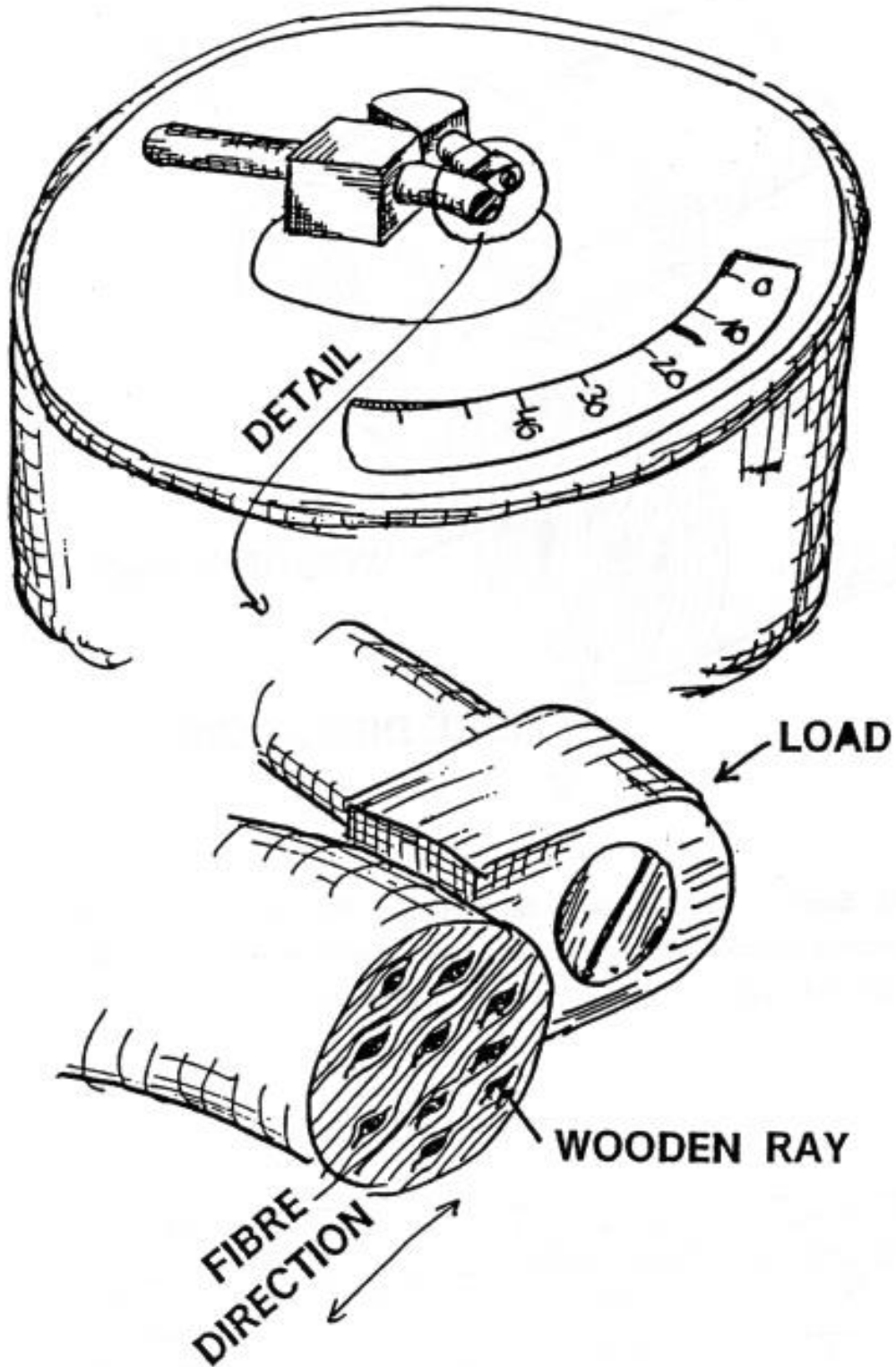


Fig. 4: The positioning of the wooden fibres in the plane of the FRACTOMETER – face guarantees a bending of the core similar to the natural wind loading. The wooden rays are bent in their stiffest direction.

INSTRUCTIONS FOR USE: FRACTOMETER I

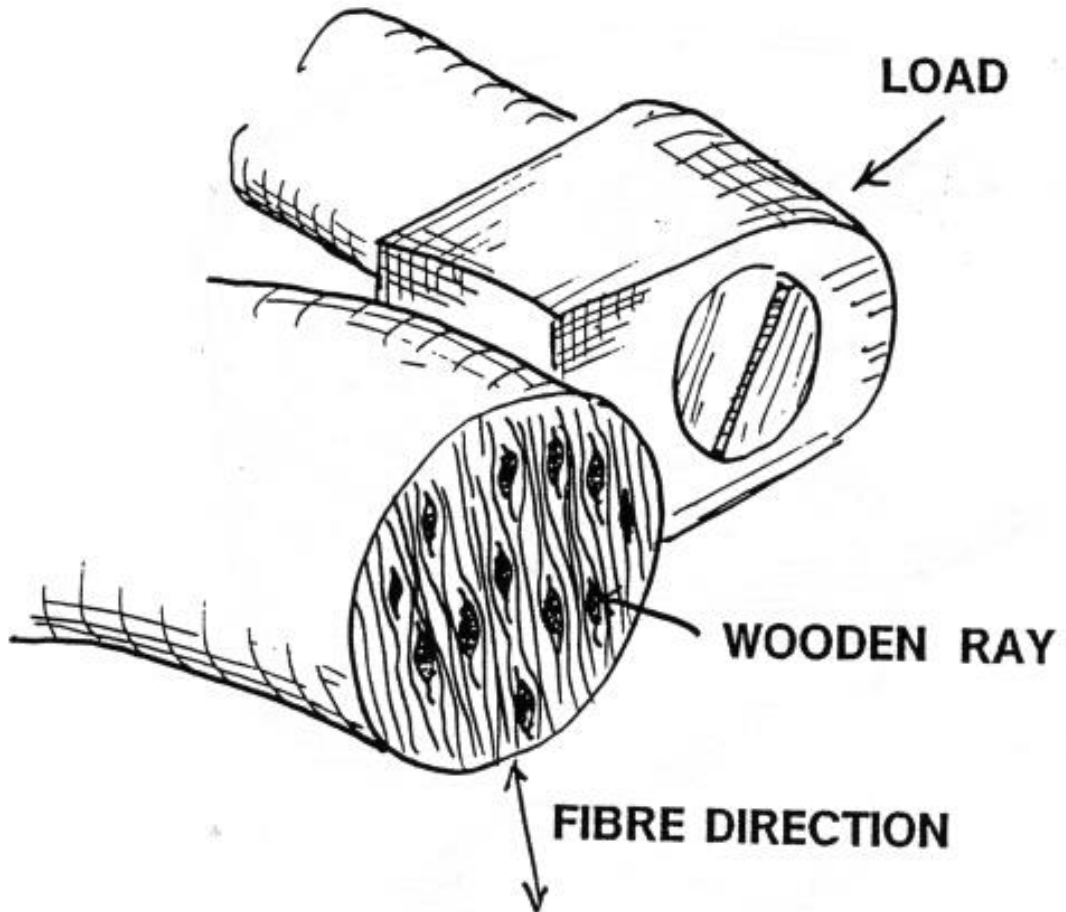


Fig. 5: When the fibres are perpendicular to the FRACTOMETER- face the wooden rays are bent in their flexiblest direction. This may lead to a reduced stiffness and/ or strength depending on the distribution of the rays over the core cross- section.

FACTOMETER fracture moment	FRACTOMETER fracture angle	Decay defect	Wood property
large	small	low	high stiffness high strength
large	large	Lignin destruction	low stiffness high strength
small	small	Cellulose destruction	high stiffness low strength
small	large	Lignin and cellulose destruction	low stiffness low strength

Fig. 6: This table for evaluation of the wood quality according to the FRACTOMETER values explains the effects of decay and the remaining wood quality.

INSTRUCTIONS FOR USE: FRACTOMETER I

MAINTENANCE

On principle, maintenance of the Fractometer will be carried out by the manufacturer or by an authorized service company. According to the conditions of guarantee, the Fractometer should be send in for a first inspection after one year at the latest.

GUARANTEE CONDITIONS

The term of guarantee for the Fractometer is 12 month. The guarantee is based on the condition that the instrument will be used exclusively for the purposes it has been designed for and the safety instructions below are observed. The manufacturer will not be liable for damages owing to inappropriate utilization or handling. The warranty for defects does not cover normal wear and tear (wearing parts) nor damages resulting from inappropriate or negligent handling and excessive strain that have not been provided in the contract of purchase.

(Please also refer to the manufacturer's „General Terms of Business“)

INSTRUCTIONS FOR UTILIZATION

The user accepts the manufacture's instruction for utilization, when he operates the instrument for the first time. The instrument must not be operated unless the user has thoroughly read the present instructions for use. The manufacturer will not be liable for damages owing to inappropriate handling, employment of the instrument for purposes that are not provided in the present instructions for use, and non-observance of the safety instructions.

SAFETY INSTRUCTIONS

The instrument must not be utilized other than the purpose described in the present instructions for use (examination of wood or material that is similar to wood). The manufacturer (vendor) will not be liable for inappropriate employment of the instrument.

The buyer agrees to hand the present instructions of use over to any person whom he may lend the instrument and to draw his/her attention to the important notes concerning danger.

NOTE:

For normal utilization of the Fractometer, opening the instrument will not be required. If the Fractometer has been opened by any person other than authorized by IML, all claims for guarantee will become extinct.

INSTRUCTIONS FOR USE: FRACTOMETER I

Materials:

The Fractometer measuring instrument has been designed for use of wooden materials such as; trees, beams and poles. Inappropriate utilization may cause damages to the measuring system and/or the material to be examined.

Certainty of Reading:

The measuring results gathered by utilizing the Fractometer system are not self-explanatory, they require qualified interpretation. Any conclusions with respect to the examined object (ex. Core sample of tree) will be left to the sole responsibility of the person who performs the examination.

The manufacturer of the instruments will not be responsible for wrong interpretations and conclusions. IML recommends to attend one of our seminars or workshops!

GENERAL INFORMATION

Concept Goals:

It was the intention of those who developed the Fractometer system to design a measuring instrument which is easy to handle, sturdy, and precise at the same time.

Moisture:

During storage and utilization of the Fractometer measuring system, one should generally avoid the contact of water and moisture, despite its splash-proof casing. Although the main components are protected against intake of water, one should – in order to avoid malfunction or failure – consider that instruments are generally sensitive to moisture!

INSTRUCTIONS FOR USE: FRACTOMETER I

ACCESSORIES

FRACTOMETER I

Serial No.:

Item:

- 4000110 **Wooden holder**
for attaching the FRACTOMETER I
Incl. Hand knobs for ergonomically favorable operation
- 4000120/ 1 **Increment Borer “SUUNTO“**
length 300 mm / 400 mm
- 4000145 **Lengthening piece and withdrawal aid**
for Increment Borer “SUUNTO“ 300/ 400
- 4000146 **Analysis testing pin**
for Increment Borer „SUUNTO“ 300/ 400
length 800 mm
- 4000127 **Maintenance Set for Increment Borer “SUUNTO“**
Plastic box, ejector for drilling cores, conical grindstone
for interior of drill, straight grindstone for exterior of drill,
oil can and 2 spare drill locks, cleaning brush with extension.
- 4000126 **Maintenance Set including Increment Borer**
“SUUNTO“ and bearing battens
Increment Borer “SUUNTO“ 400/5 mm, bag for bearing
battens ,plastic box, ejector for drilling cores,
6 supporting battens, cleaning brush with extension,
conical grindstone for interior of drill, straight grindstone
for exterior of drill, oil can, glue can and 2 spare drill locks.
- 4000128 **Ejector**
The Ejector serves for ejecting drilling cores out of the
Increment Borer without damaging them. The risk of injury
during the ejection of a drilling core is reduced to a minimum
by the plastic casing to be slid over the drill.

INSTRUCTIONS FOR USE: FRACTOMETER I

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IML- Instrumenta Mechanik Labor System GmbH

Parkstraße 33, 69168 Wiesloch - Germany

Phone: +49 6222 6797-0, Fax: +49 6222 6797-10

Website: www.iml.de ; E- mail: info@iml.de