PURDUE UNIVERSITY

Hardwood Scanning Center

Forestry & Natural Resources

PURDUE UNIVERSITY

Innovations in Wood Processing

Rado Gazo

March 2013

San Jose, Costa Rica

Indiana's Primary Industry
(logging, sawmills, veneer, plywood, etc.)


- 601 firms in the primary industry of Indiana
- 21,692 individuals are employed by the primary industry
- $563 million dollars in wages were paid by the primary industry


Indiana's Secondary Industry
(furniture, fixtures, etc.)

- 509 firms comprise the secondary wood products manufacturing industry in Indiana
- 69 of the 300 largest U.S. furniture, cabinet, and millwork manufacturers have plants in Indiana
- 10 of the largest kitchen cabinet manufacturers have headquarters or plants in Indiana
- 26,150 individuals are employed by the secondary industry
- $666 million in wages were paid by the secondary industry

Secondary Wood Processing

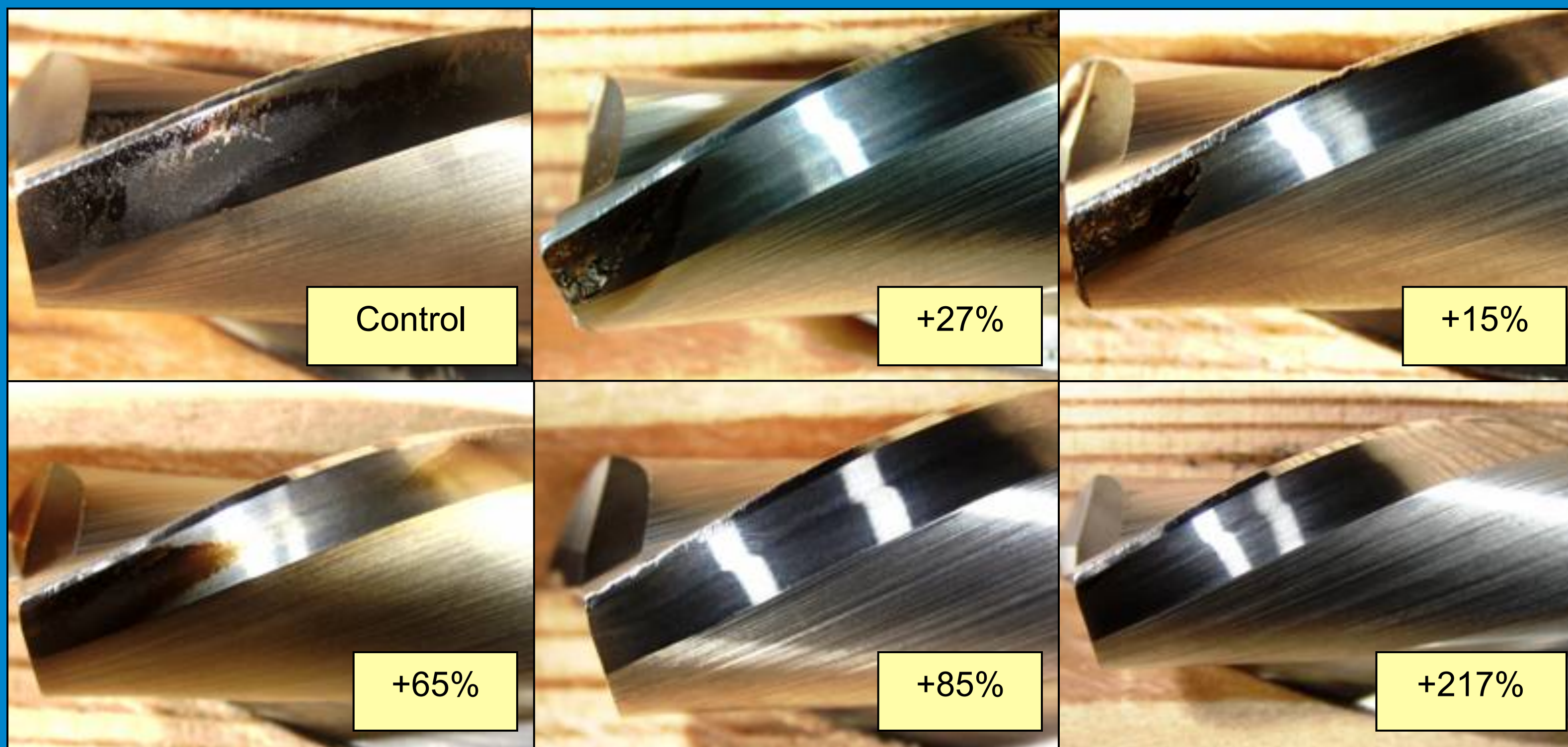
Example: Cryogenic Treatment of Tools

The Effect Cryogenic Treatment on Tool Wear in Machining

70°F (21°C) 40°F (4.4°C) 20°F (-6.7°C)

Untreated

Treated



Estimated increase in tool life

Primary Wood Processing

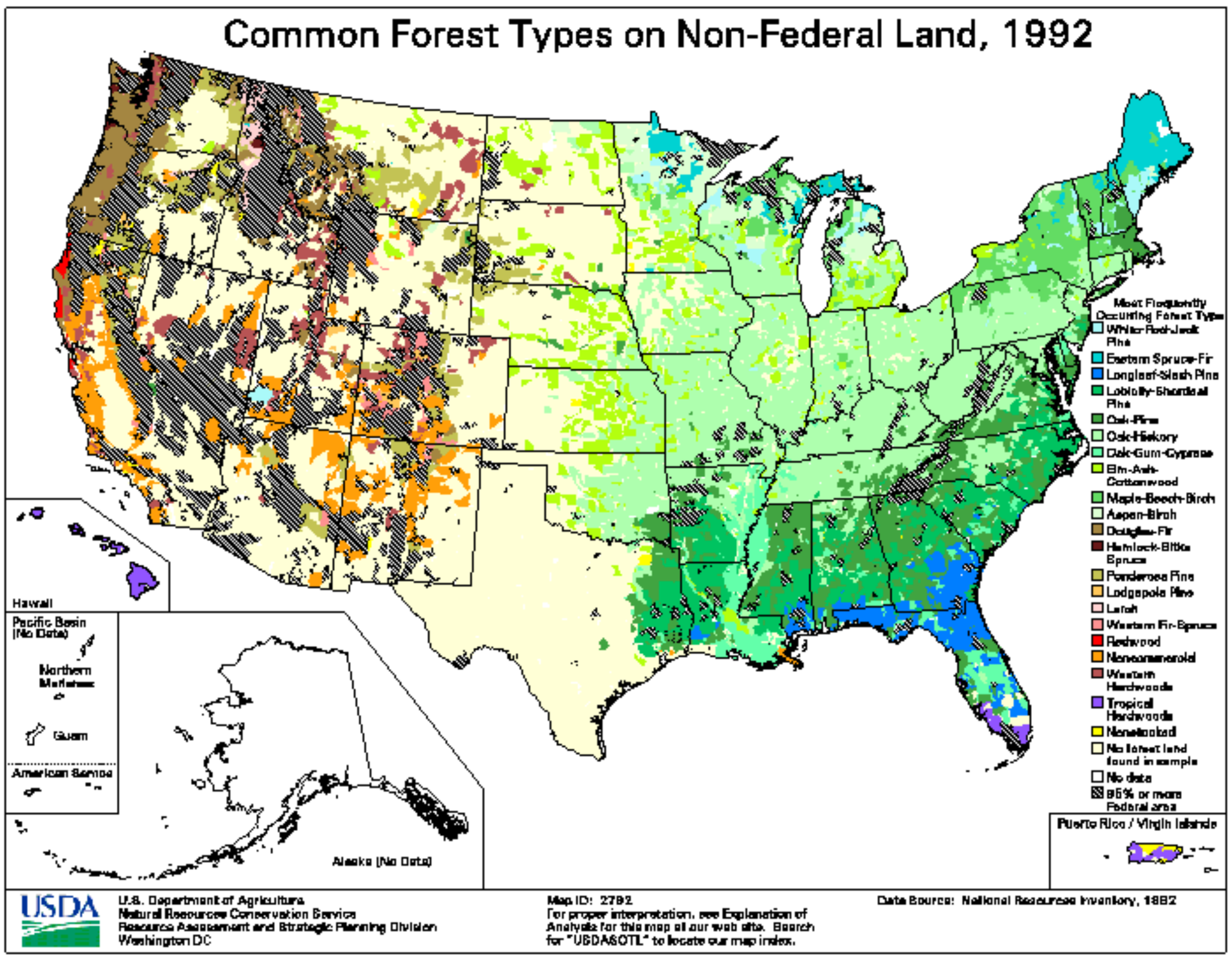
Example: CT Scanning of Logs

Past scanning studies

Numerous past research studies have examined log breakdown value improvements.

Year	Author	# of Logs	Species	% Improvement
1962	Peter	10	Southern Pine	3%
1967	Peter	50	Yellow Poplar	9%
1969	Tsolakides	6	Red Oak	21%
1975	Wagner and Taylor	10	Southern Pine	8%
1980	Richards *et al.*	320	Red Oak	11%
1989	Steele *et al.*	24	Red Oak	12%
1994	Steele *et al.*	6	Red Oak	10%
'94-'99	Chang and Guddanti	10	Red Oak	18% -28%

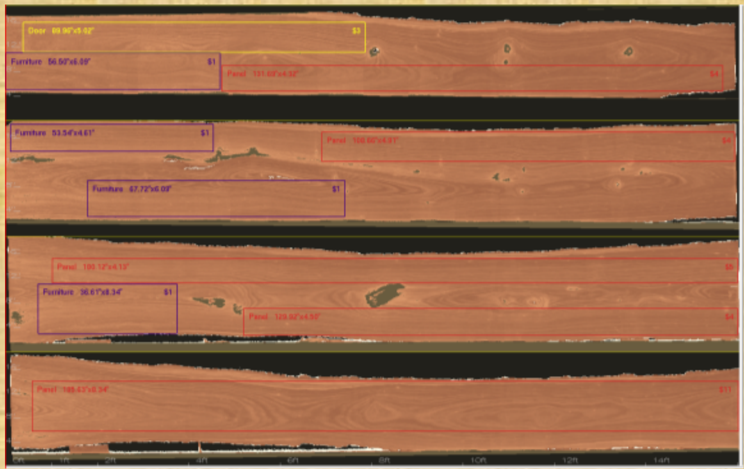
Softwood vs. Hardwood Log Processing



Softwood vs. Hardwood Log Processing

- Softwoods – grading system is based on prediction of strength of lumber.
- Production process is more automated and much faster.

- Hardwoods – grading system is based on appearance characteristics of lumber or sliced veneer.
- Production process relies heavily on experience and skill of operator (headrig, resaw, edger).



Hardwood Scanning Center Goal

- Help in development of Hardwood Log CT scanner
- Develop optimization software
- Assist in industry adoption of CT scanning technology

Proof of Concept

- 60 Logs
- 5 Species (Black Cherry, Yellow Poplar, Red Oak, White Oak and Hard Maple)
- 3 Log Grades (Grade 1, 2 and 3)
- 4 Logs (2 pairs) per grade
- Pair is a close match in diameter, length, location within a tree and defects
- Logs were 10’ to 16’ long and up to 16” in diameter

Proof of Concept

Proof of Concept

Results – Sawmill vs. CT Scanner

Gain (%)	Black Cherry	Hard Maple	Red Oak	White Oak	Yellow Poplar	Overall
All Grades	42	33	24	60	87	**46**

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Grade 1	20	21	8	83	23	27

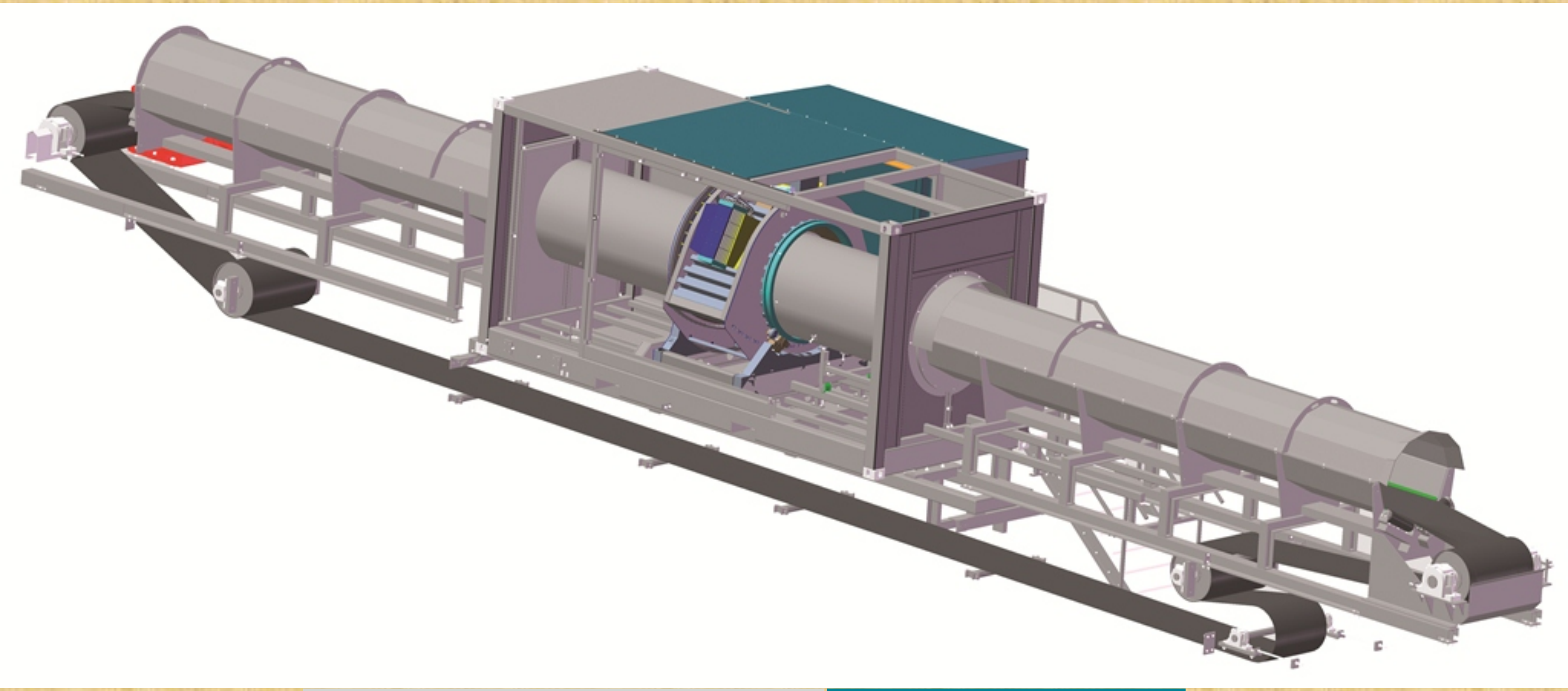
Results – Sawmill vs. CT Scanner

Gain (%)	Black Cherry	Hard Maple	Red Oak	White Oak	Yellow Poplar	Overall
All Grades	42	33	24	60	87	**46**
Grade 1	20	21	8	83	23	27
Grade 2	45	34	22	42	99	47

Results – Sawmill vs. CT Scanner

Gain (%)	Black Cherry	Hard Maple	Red Oak	White Oak	Yellow Poplar	Overall
All Grades	42	33	24	60	87	**46**
Grade 1	20	21	8	83	23	27
Grade 2	45	34	22	42	99	47
Grade 3	194	75	67	46	221	97

CT Scanner Development
Medical vs. Security



MiCROTEC® INNOVATING WOOD CT.LOG

CT Scanner Development

- Log Length: No limit
- Max. Log Diameter: 700 mm
- Gantry aperture: 1200 mm
- Max Log speed: 60 m/min
- X–Y resolution: approx. 1mm

MiCROTEC®
INNOVATING WOOD
CT.LOG


CT.LOG
MiCROTEC

Software Development

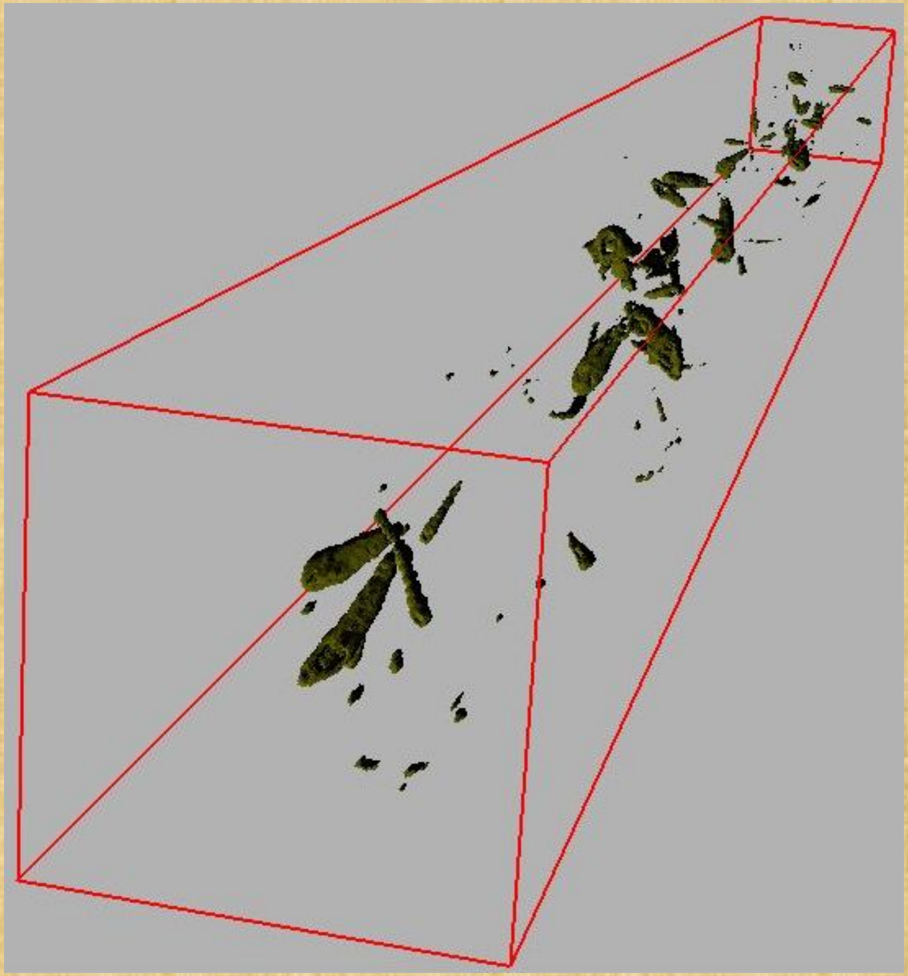
- LogView
  - Veneer (full optimization)
  - Sawmill (full optimization)

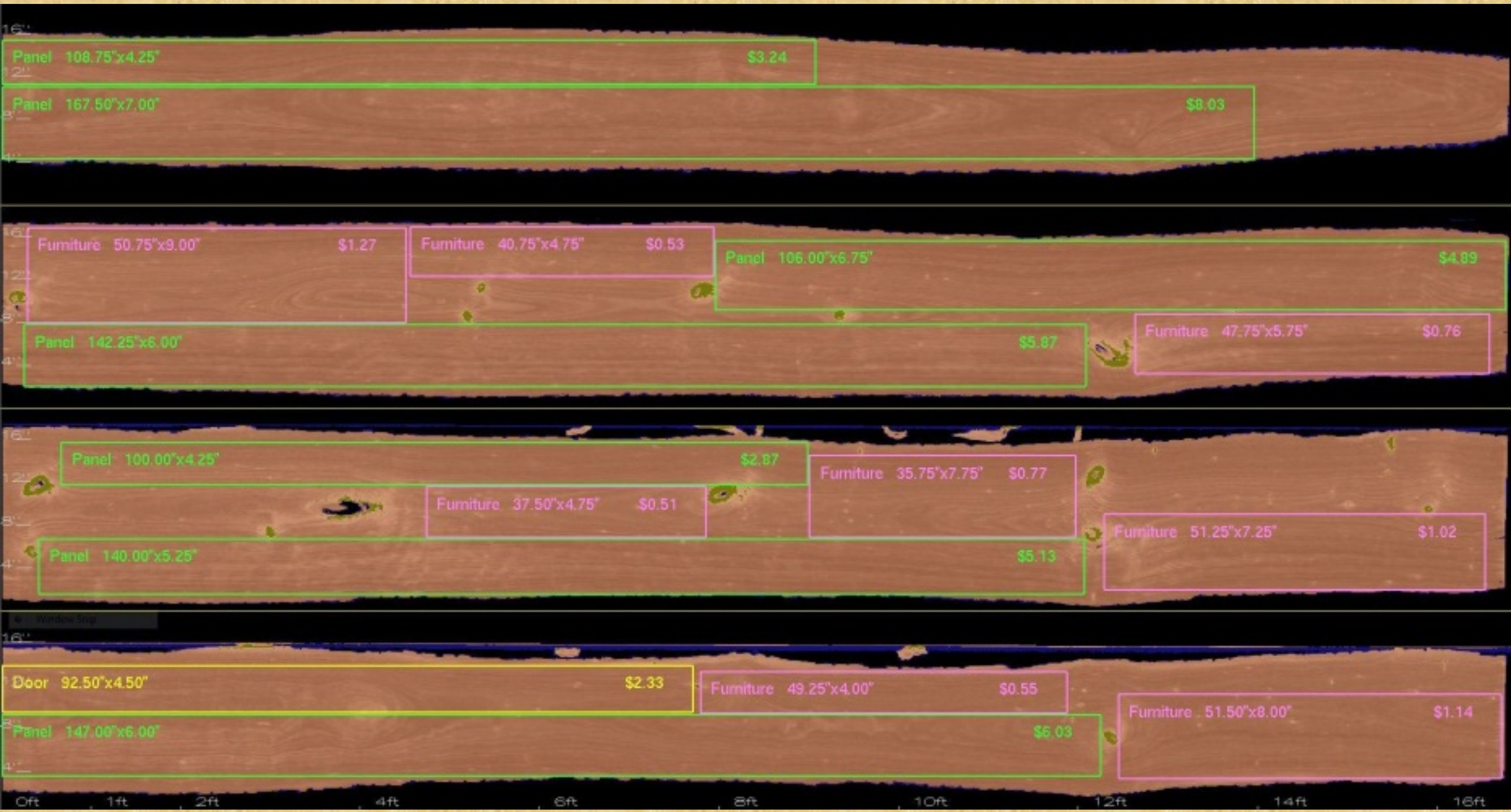
- Developed by Purdue University Hardwood Scanning Center

- Commercialized by LogView, LLC

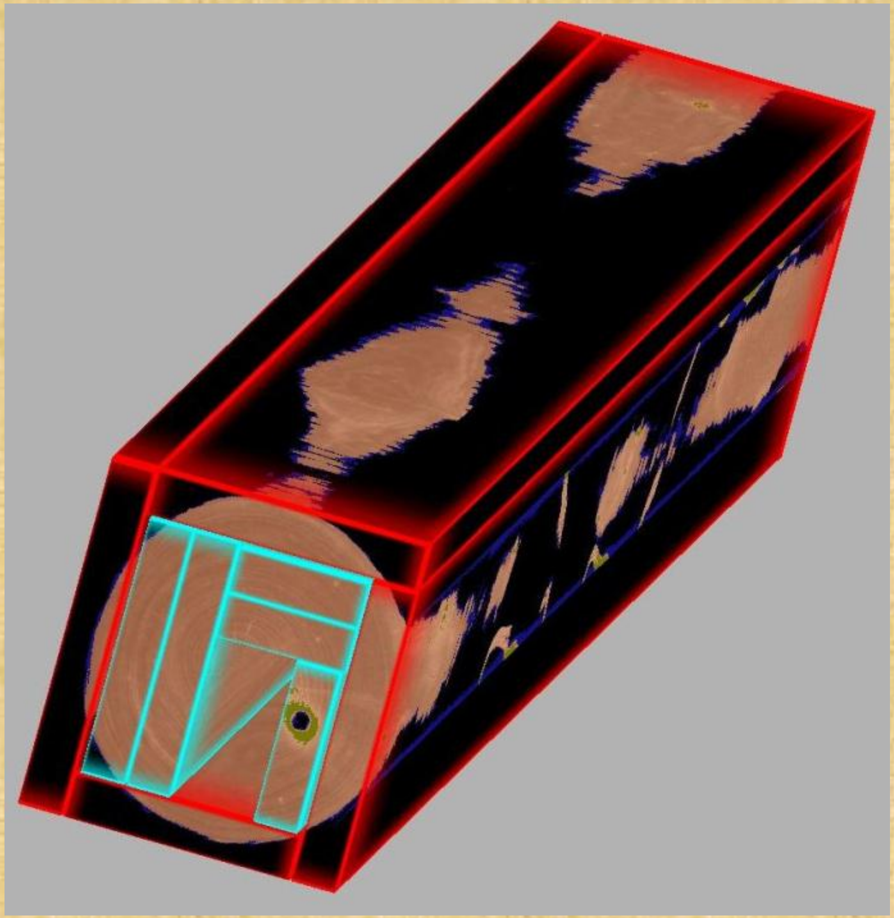
Industry Adoption

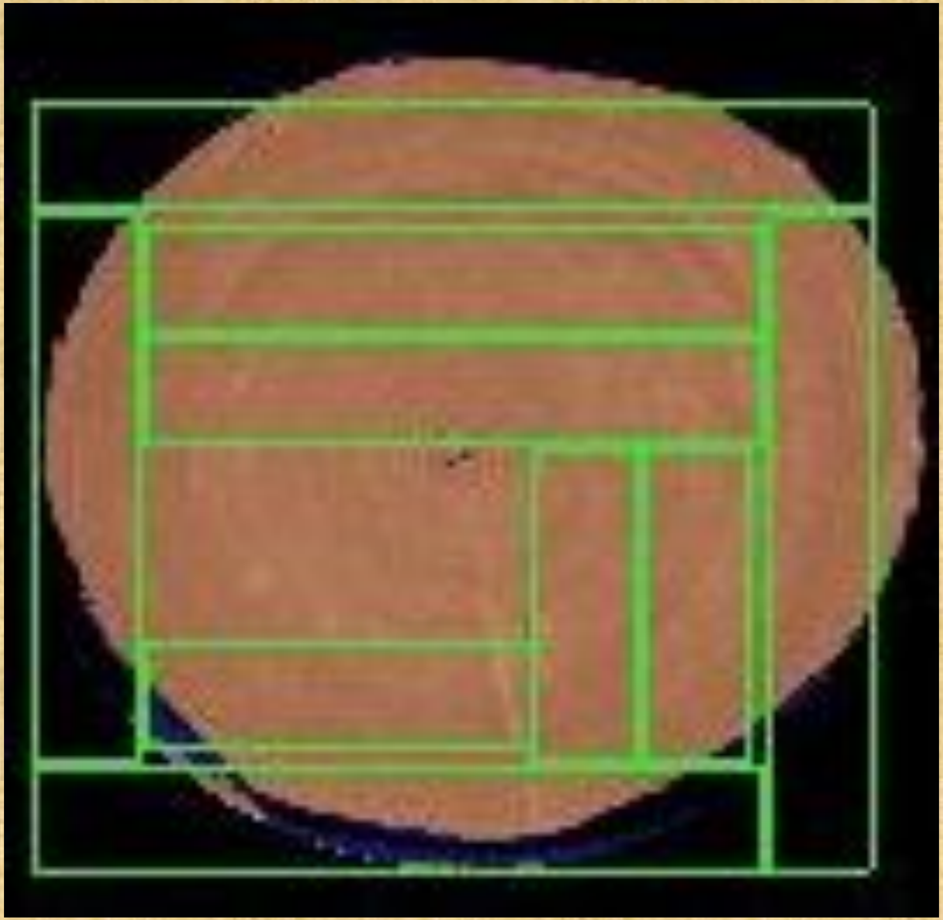
- Public test demonstration in selected mills
  - Veneer
  - Sawmill




Panel 108.75"x4.25" $3.24
Panel 167.50"x7.00" $8.03
Furniture 50.75"x9.00" $1.27
Furniture 40.75"x4.75" $0.53
Panel 106.00"x6.75" $4.89
Panel 142.25"x6.00" $5.87
Furniture 47.75"x5.75" $0.76
Panel 100.00"x4.25" $2.87
Furniture 35.75"x7.75" $0.77
Furniture 37.50"x4.75" $0.51
Furniture 51.25"x7.25" $1.02
Panel 140.00"x5.25" $5.13
Door 92.50"x4.50" $2.33
Furniture 49.25"x4.00" $0.55
Furniture 51.50"x8.00" $1.14
Panel 147.00"x6.00" $6.03
0ft 1ft 2ft 4ft 6ft 8ft 10ft 12ft 14ft 16ft


Analysis Results
$45
$33
135
90
45
0
315
270
225
180
Selected Angle 135
Total Price [$] 45
Improvement [%] 36
sq ft
Panel 16.40
Door 0.00
Desk 2.92
Furniture 36.05
Results By Method
Value
Volume
Figure
Display Options
Show Log Ends
Active Results
Result 0
Select Best Angle
The log was analyzed in:
6 s
OK





18"
0ft 1ft 2ft 4ft 6ft 8ft 10ft 12ft 14ft 16f

How and Where Can This Technology Be Applied?

- Log merchandising and bucking
- Slicing vs. Peeling
- Hardwood Veneer Slicing – Optimize splitting log into flitches (off-line or in-line)
- Hardwood Sawmills - Optimize log “opening” at headrig to maximize yield of premium product (in-line between debarker and headrig)

CT Log Scanning

Summary

- **CT Technology exists today to see *inside* a log**
- **CT Technology can be applied at various points in the process to satisfy multiple applications**

The Species

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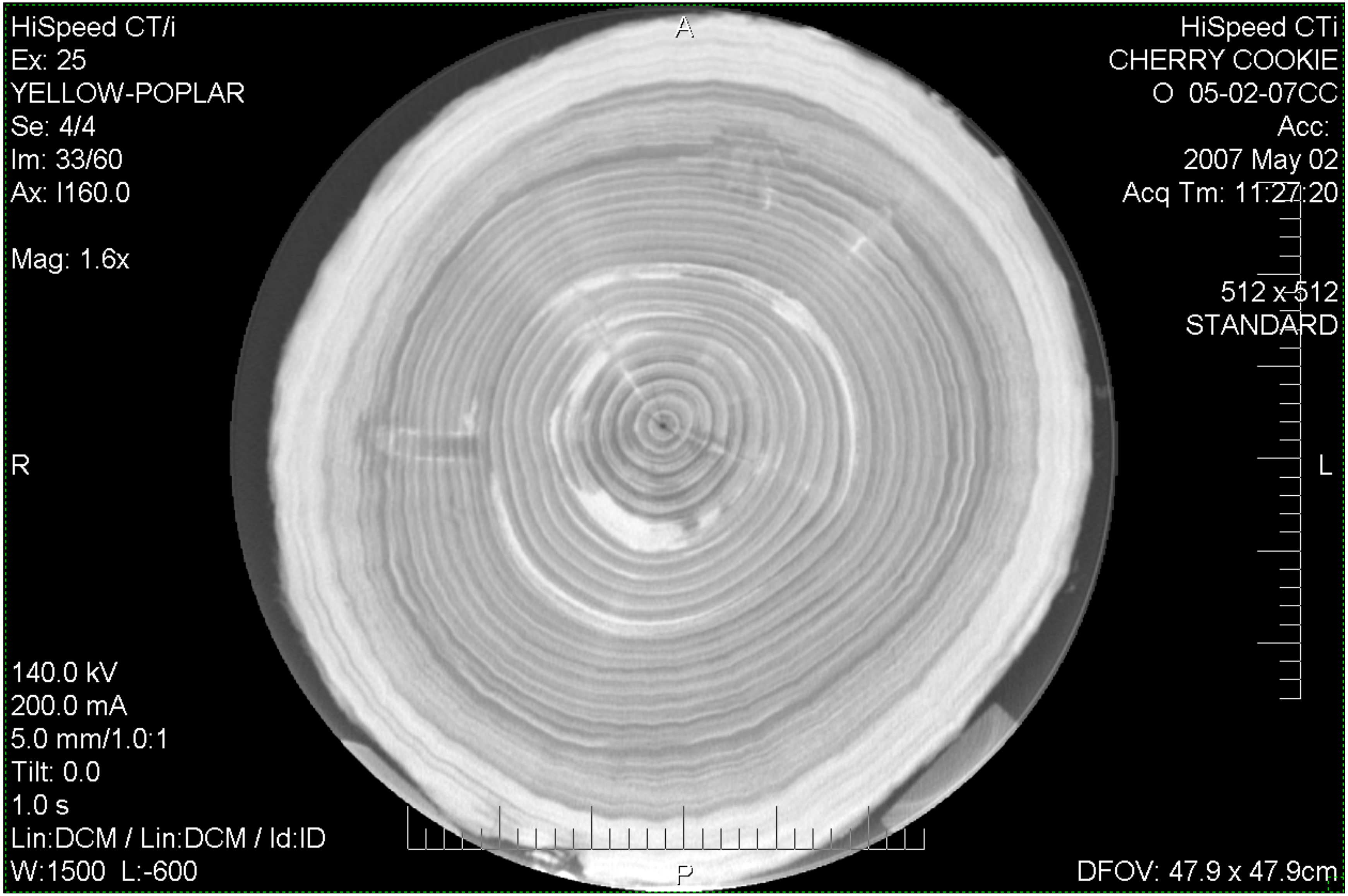

Yellow Popular

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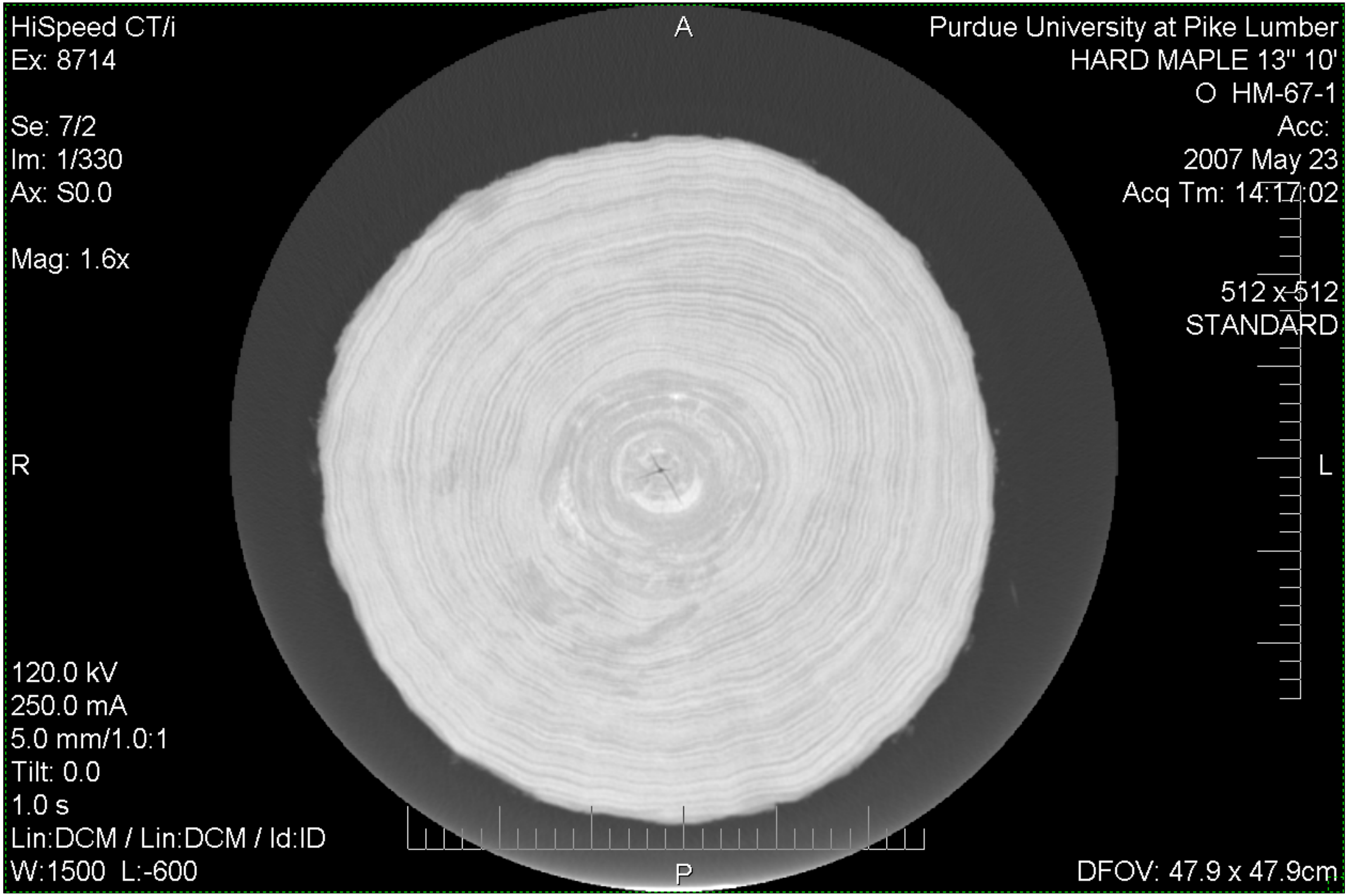
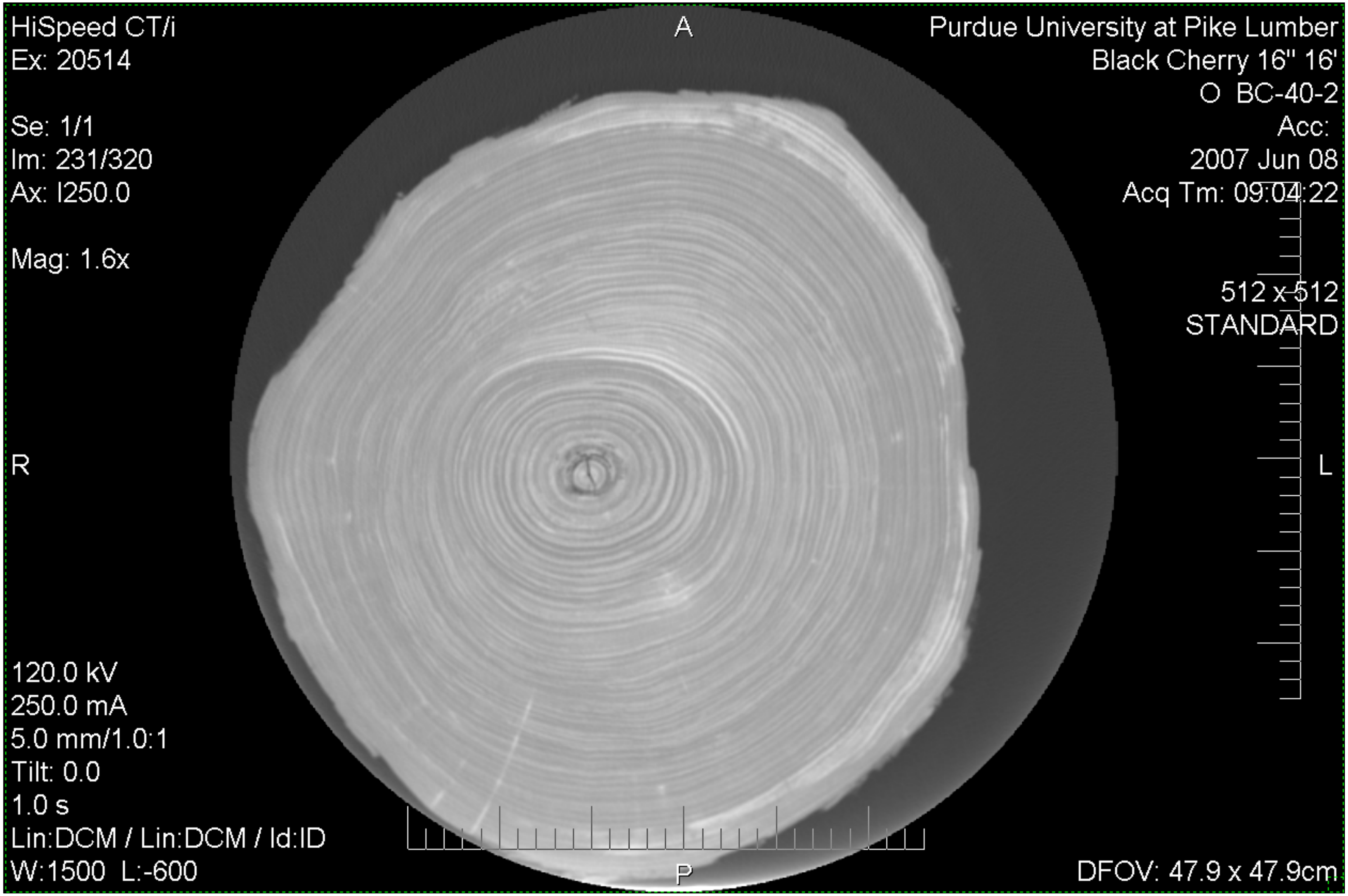


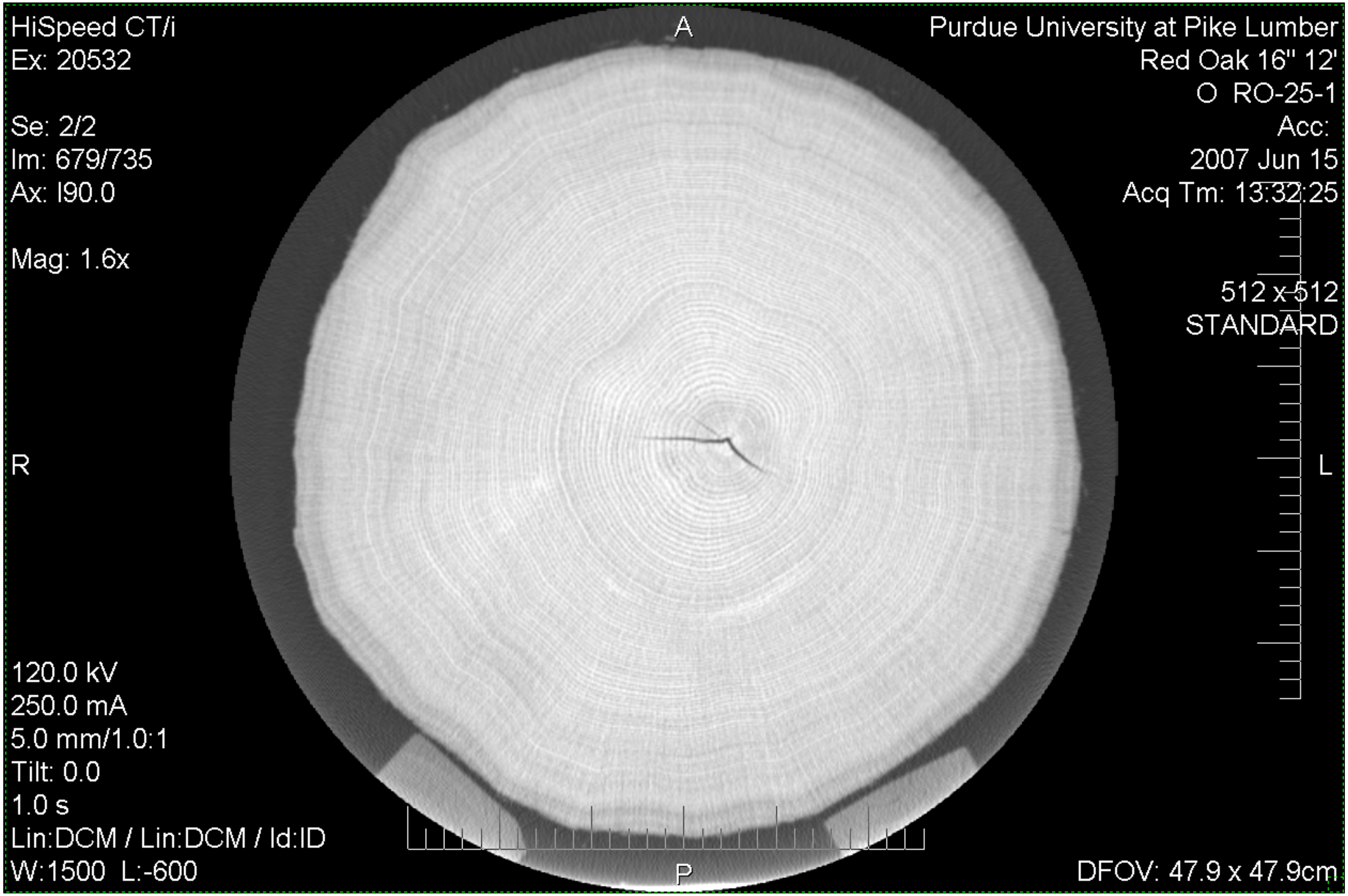
Hard Maple

Hardwood Scanning Center



Black Cherry

Hardwood Scanning Center



Red Oak

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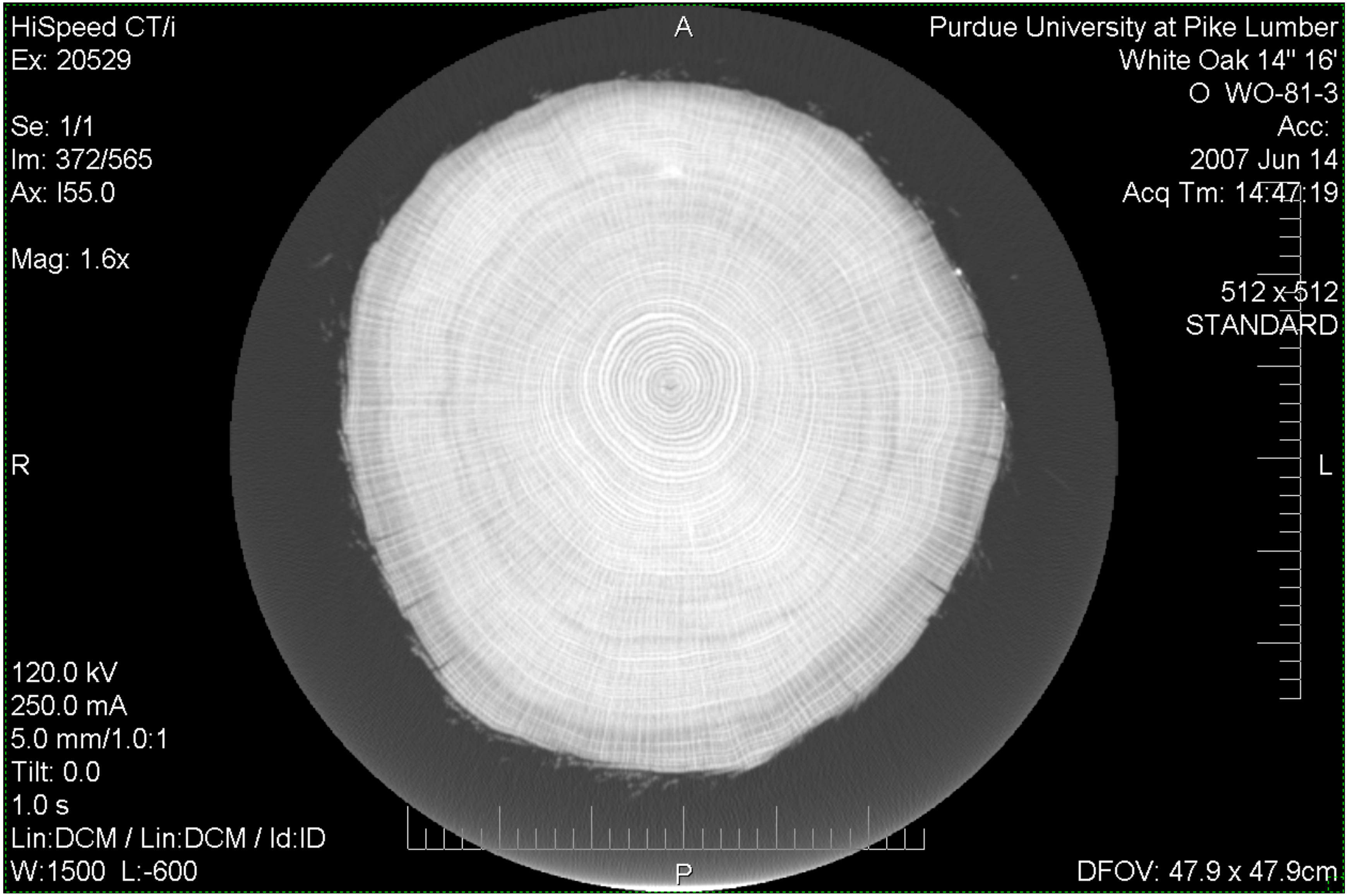


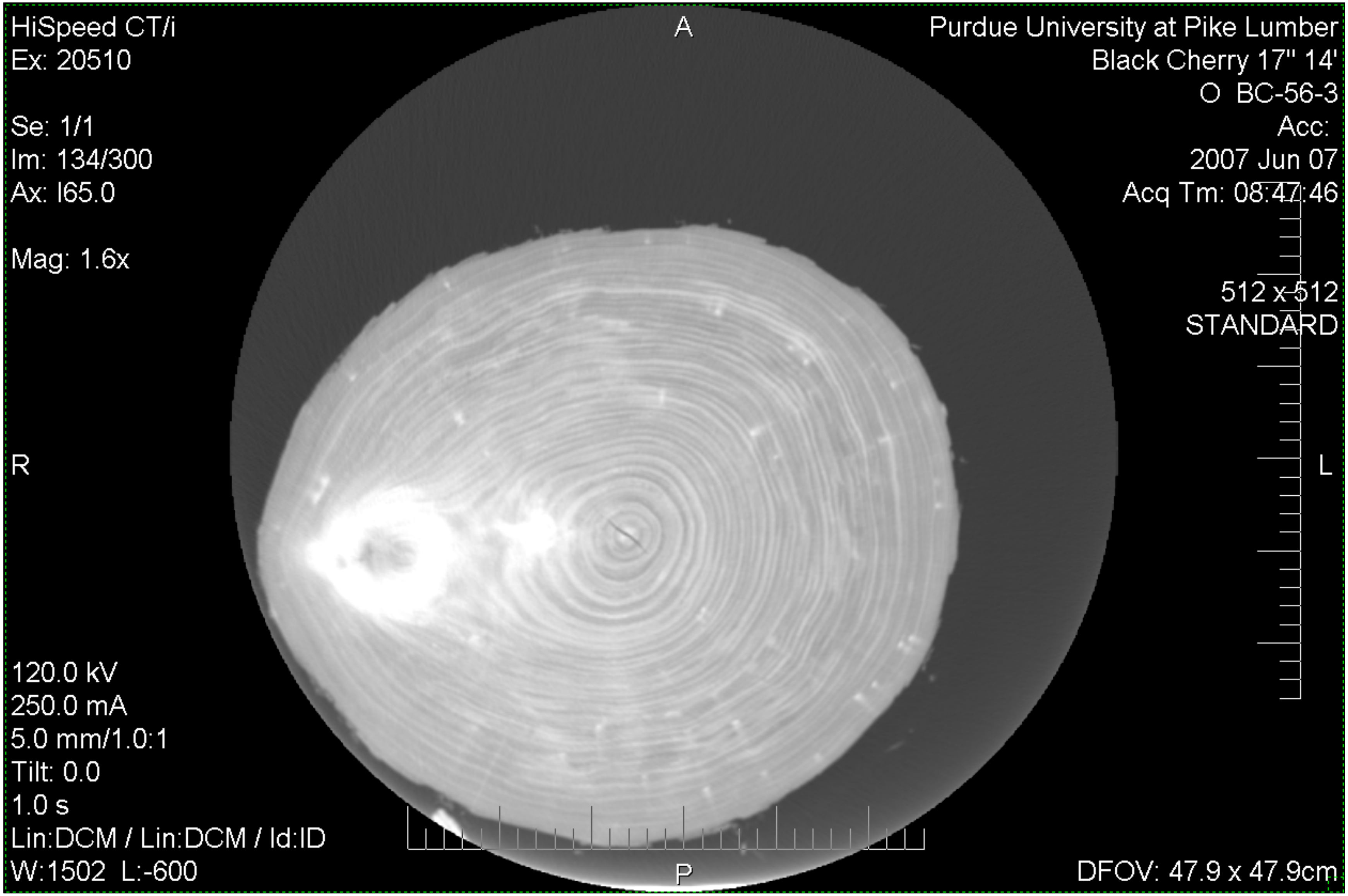
White Oak

What can we see in wood?

We can see…

Knots & Voids

Hardwood Scanning Center



Sound Knot in Black Cherry

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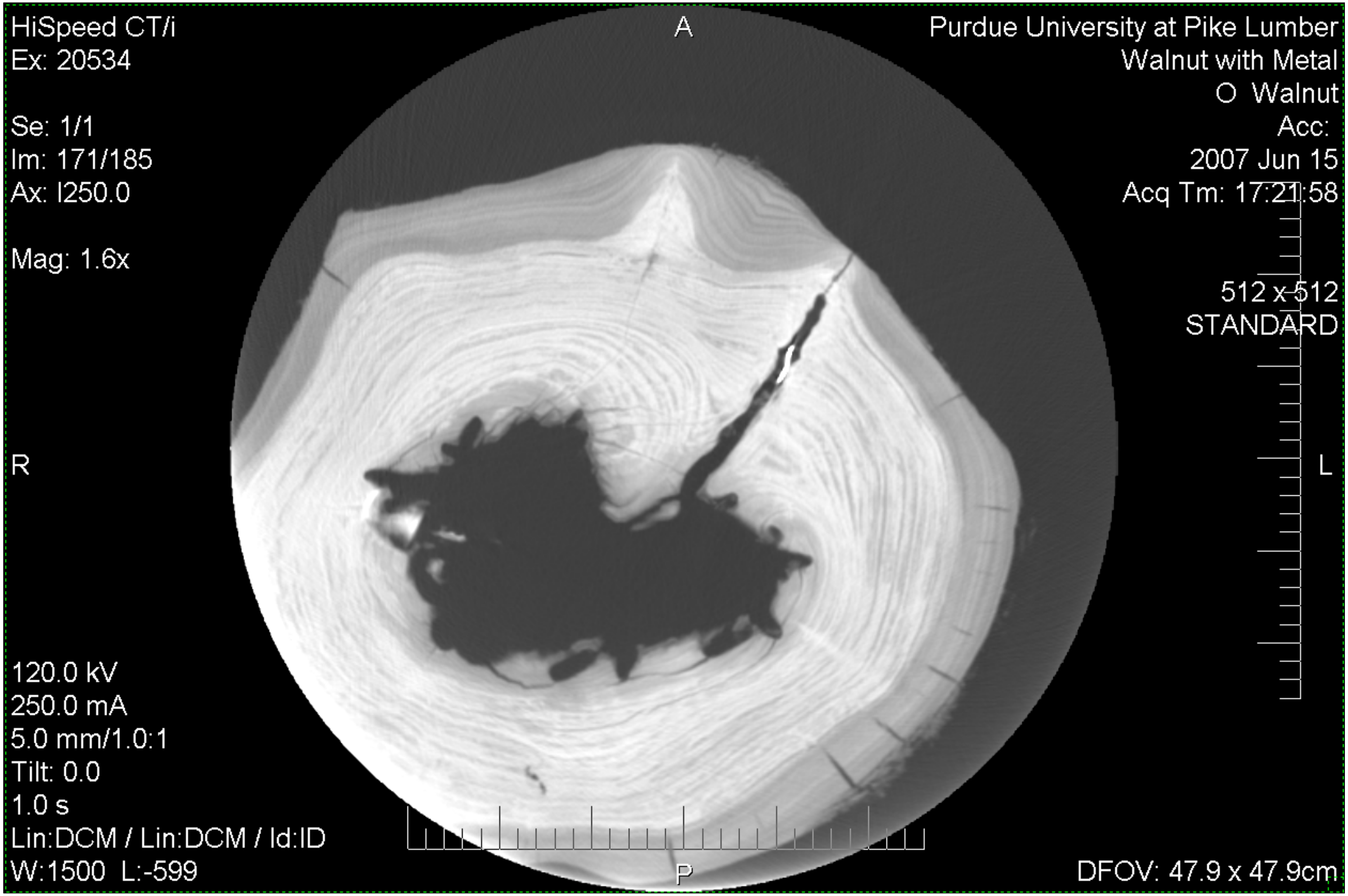
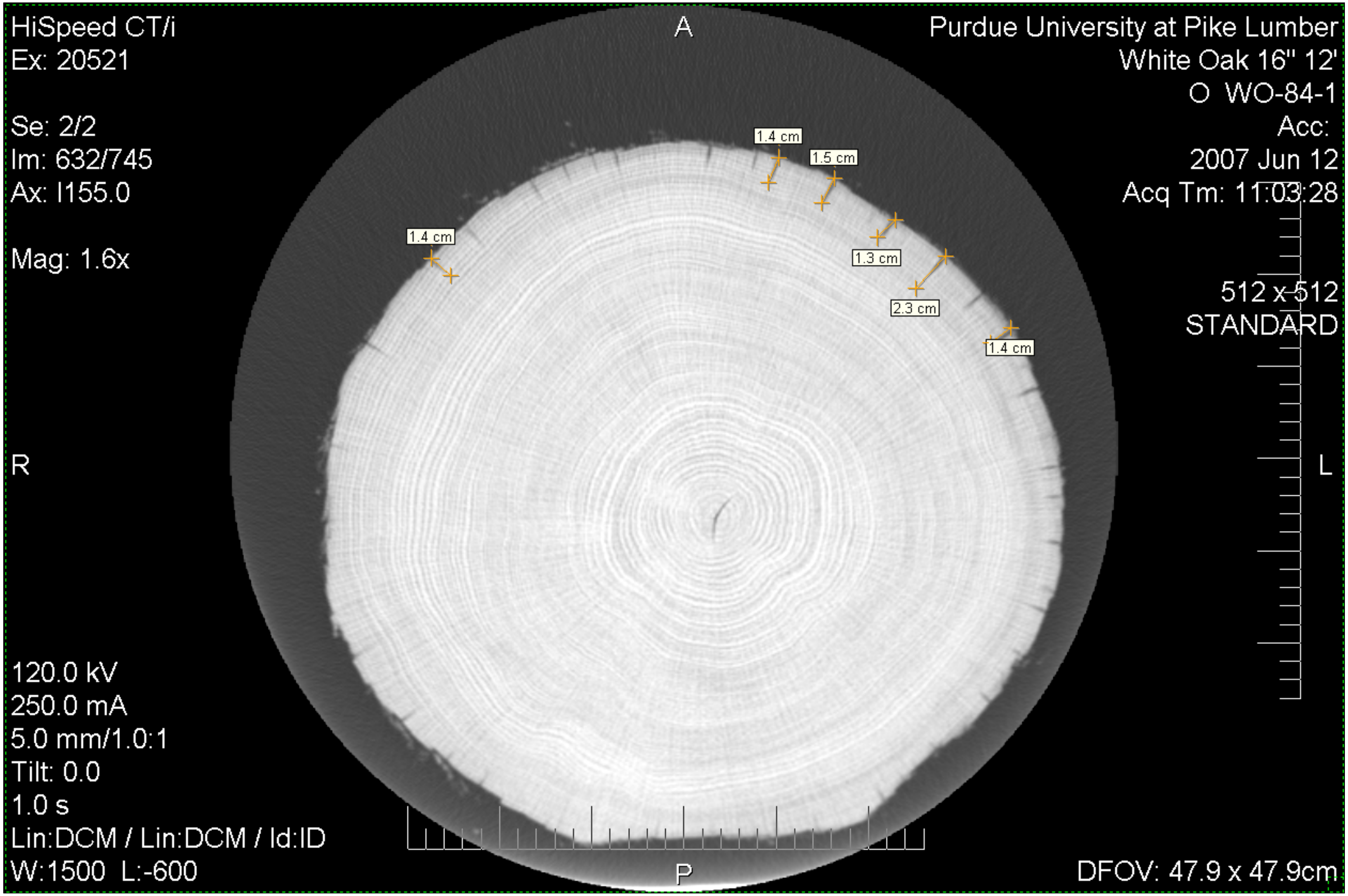
Hardwood Scanning Center



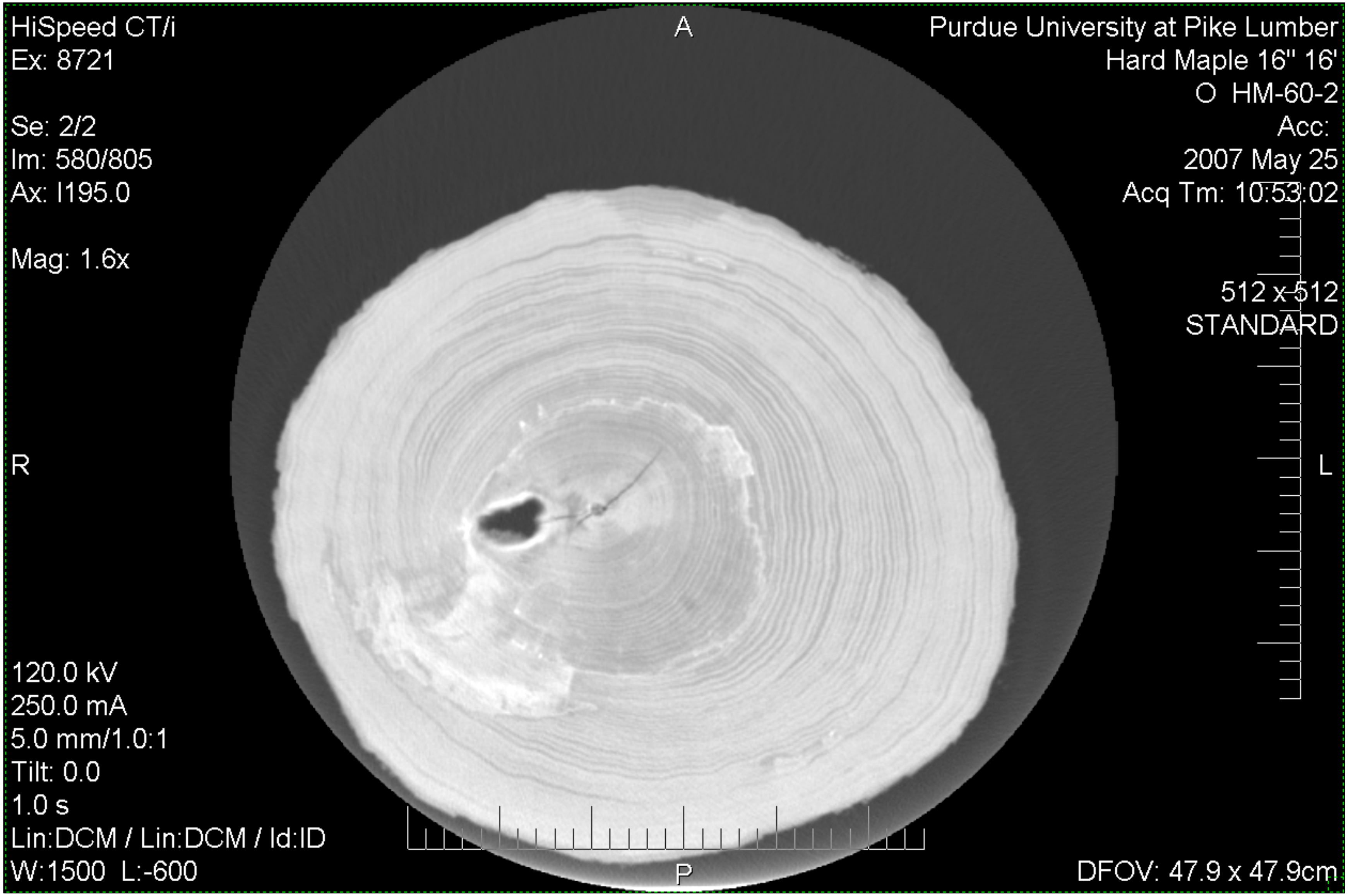
Carpenter Ants in Black Walnut

Hardwood Scanning Center



Checking In White Oak

Hardwood Scanning Center



Un-Sound Knot in Hard Maple

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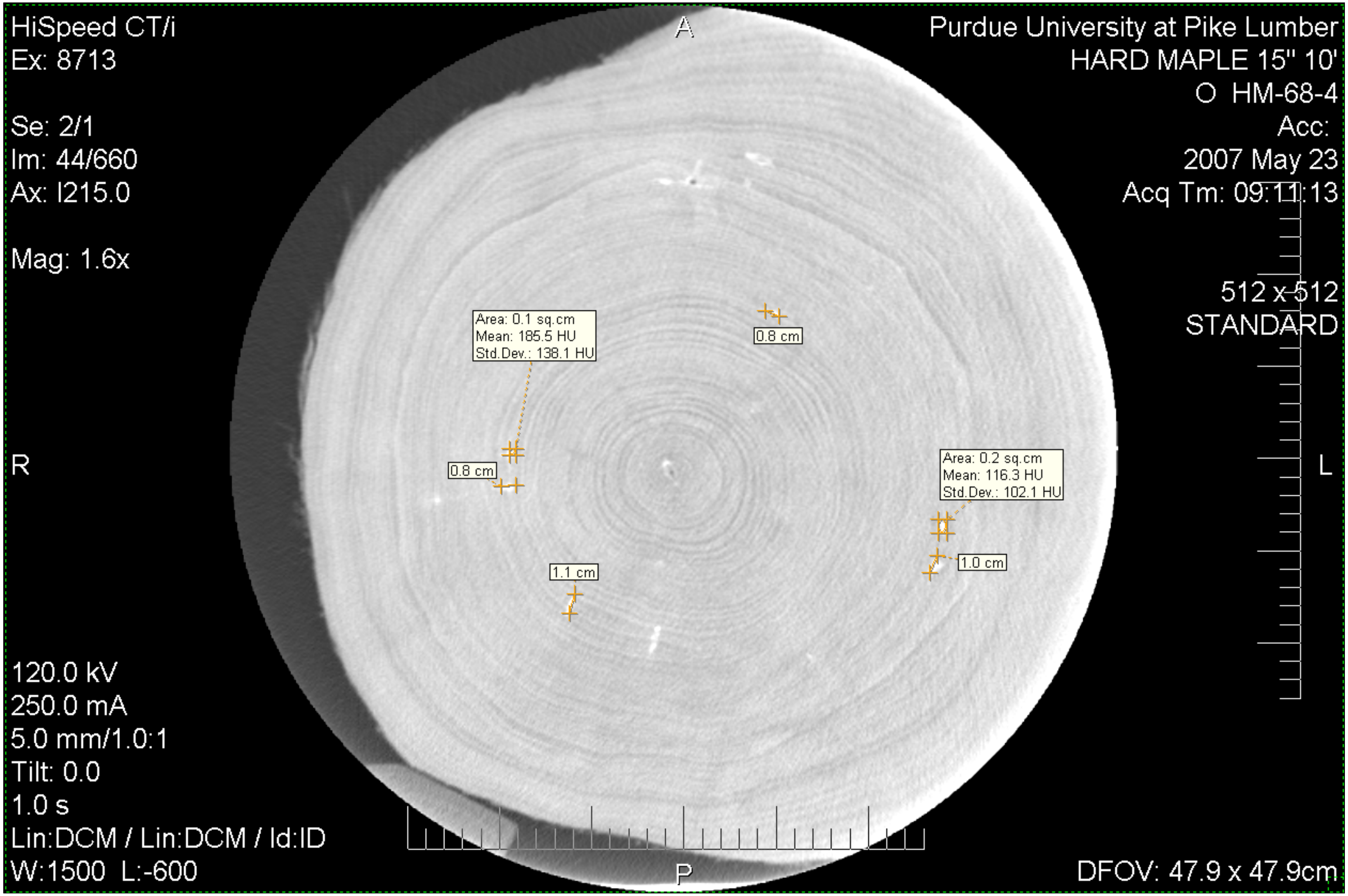
Hardwood Scanning Center

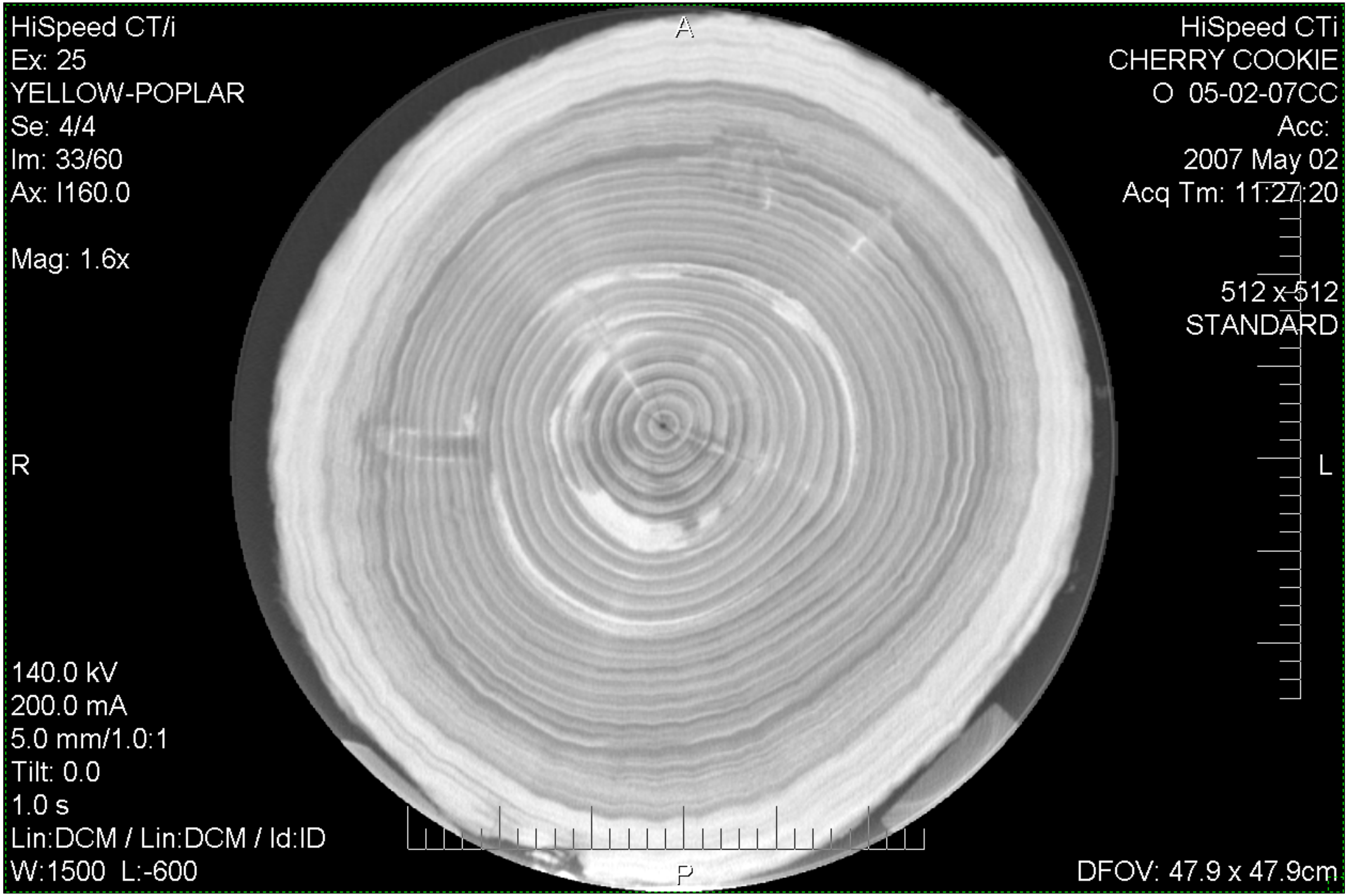


Pin Knots in Hard Maple

We can see…

Sapwood vs. Heartwood

Hardwood Scanning Center



Sap vs. Heart in Yellow Popular

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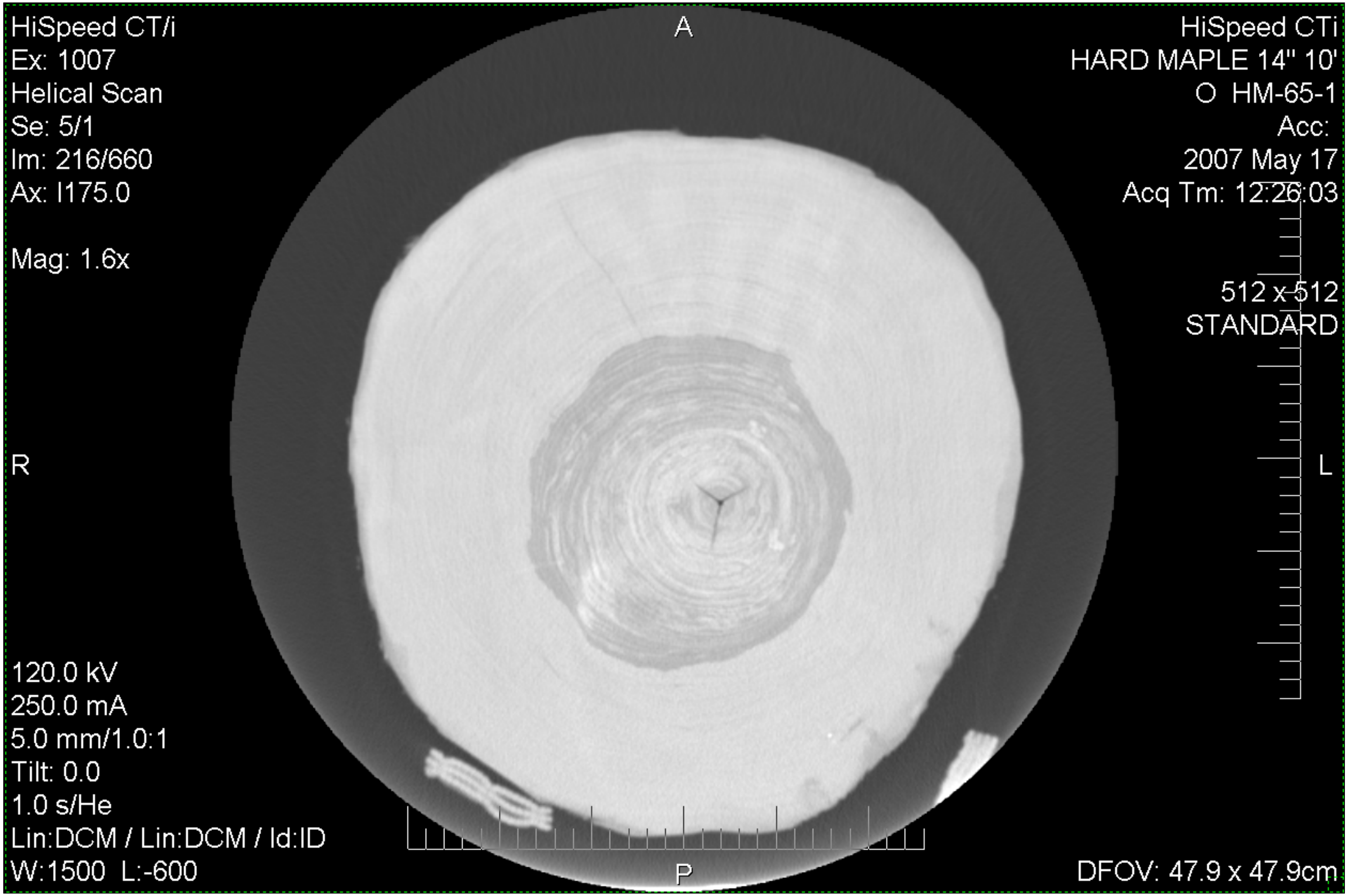
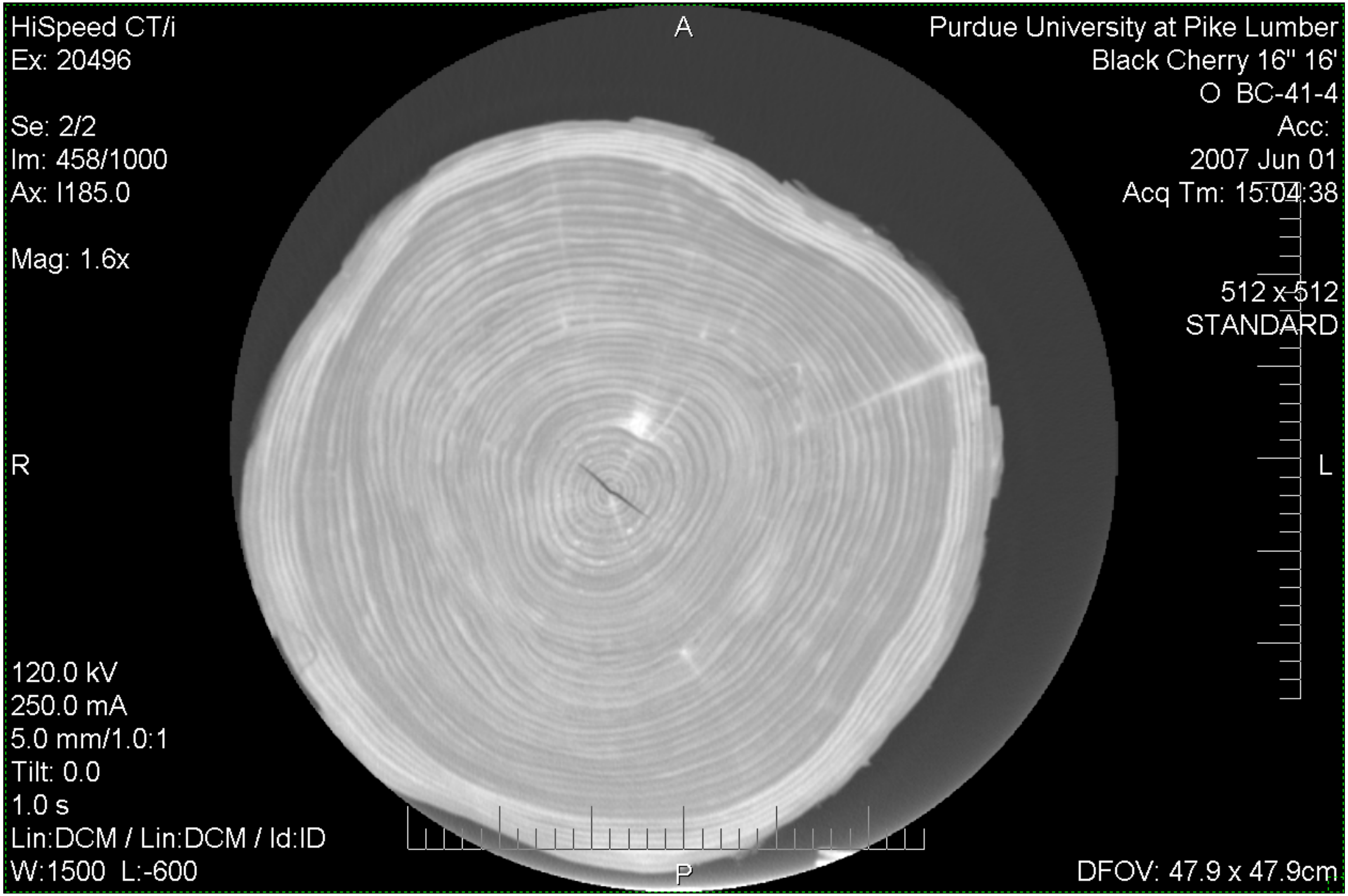
Hardwood Scanning Center



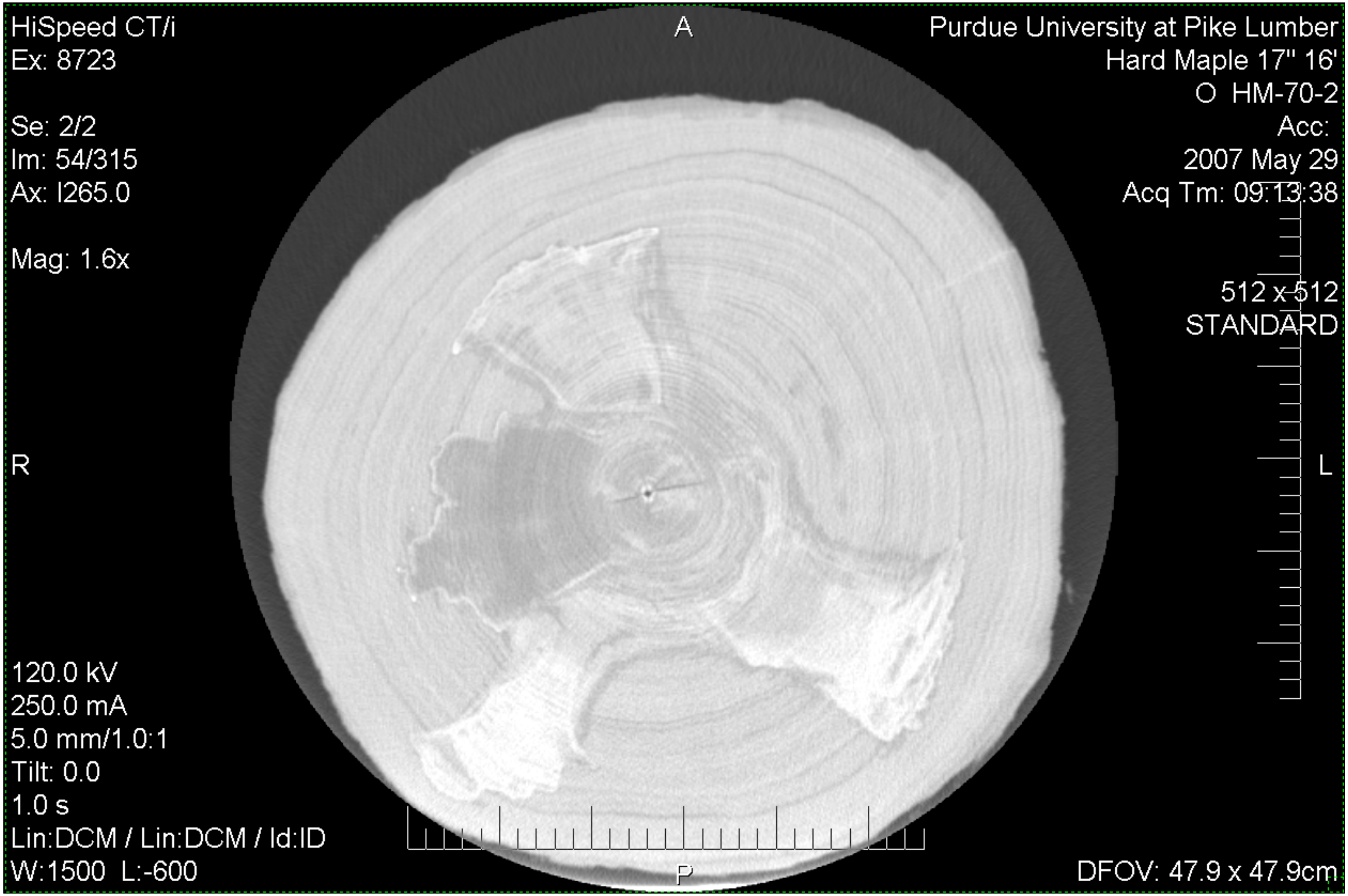
Sap vs. Heart in Hard Maple

Hardwood Scanning Center



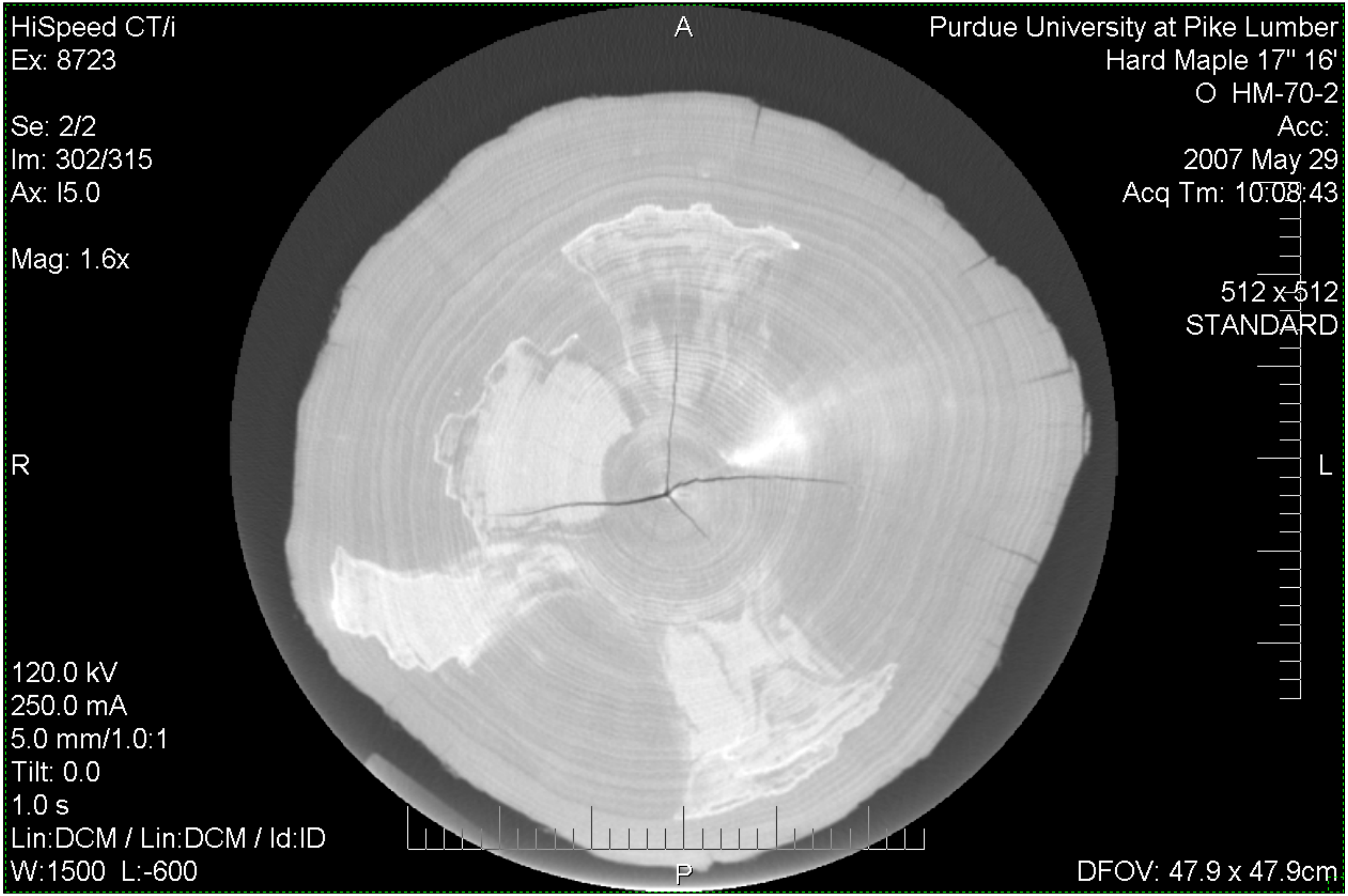
Sap vs. Heart in Black Cherry

Hardwood Scanning Center



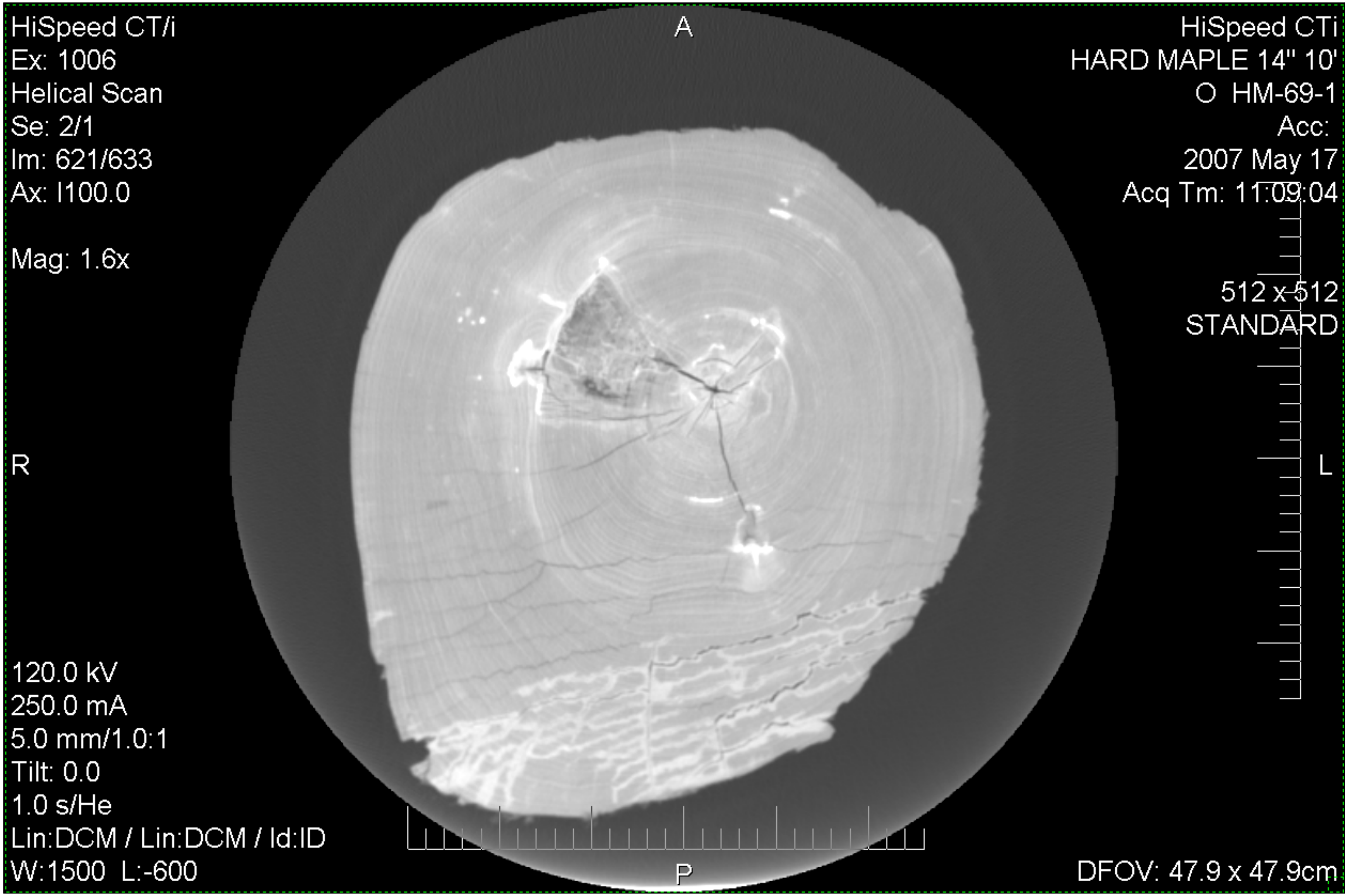
Stain in Hard Maple

Hardwood Scanning Center



Stain in Hard Maple

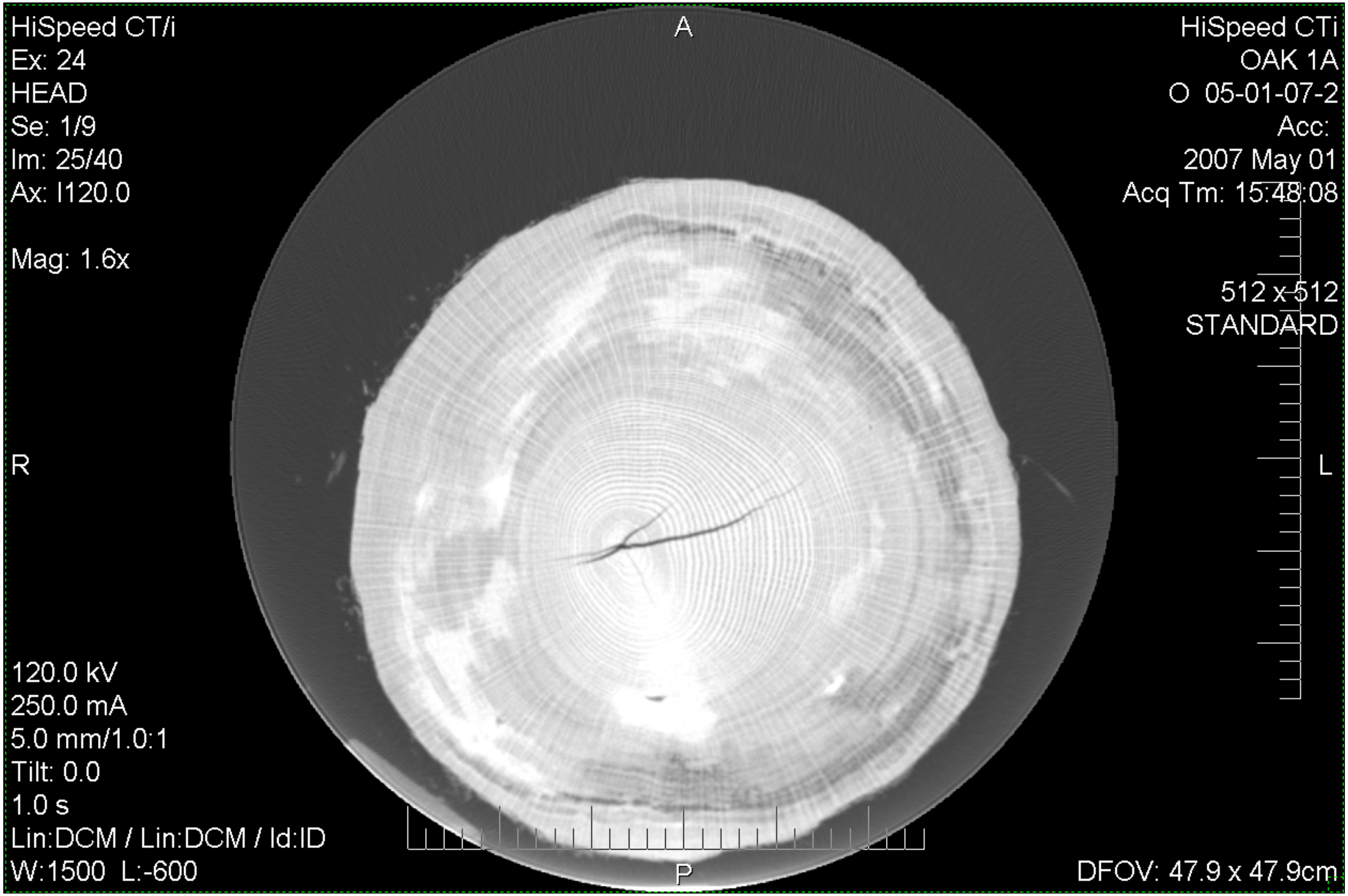
Hardwood Scanning Center



Stain in Hard Maple

Hardwood Scanning Center

PURDUE UNIVERSITY



Stain in Red Oak

We can see…

Lumber Defects

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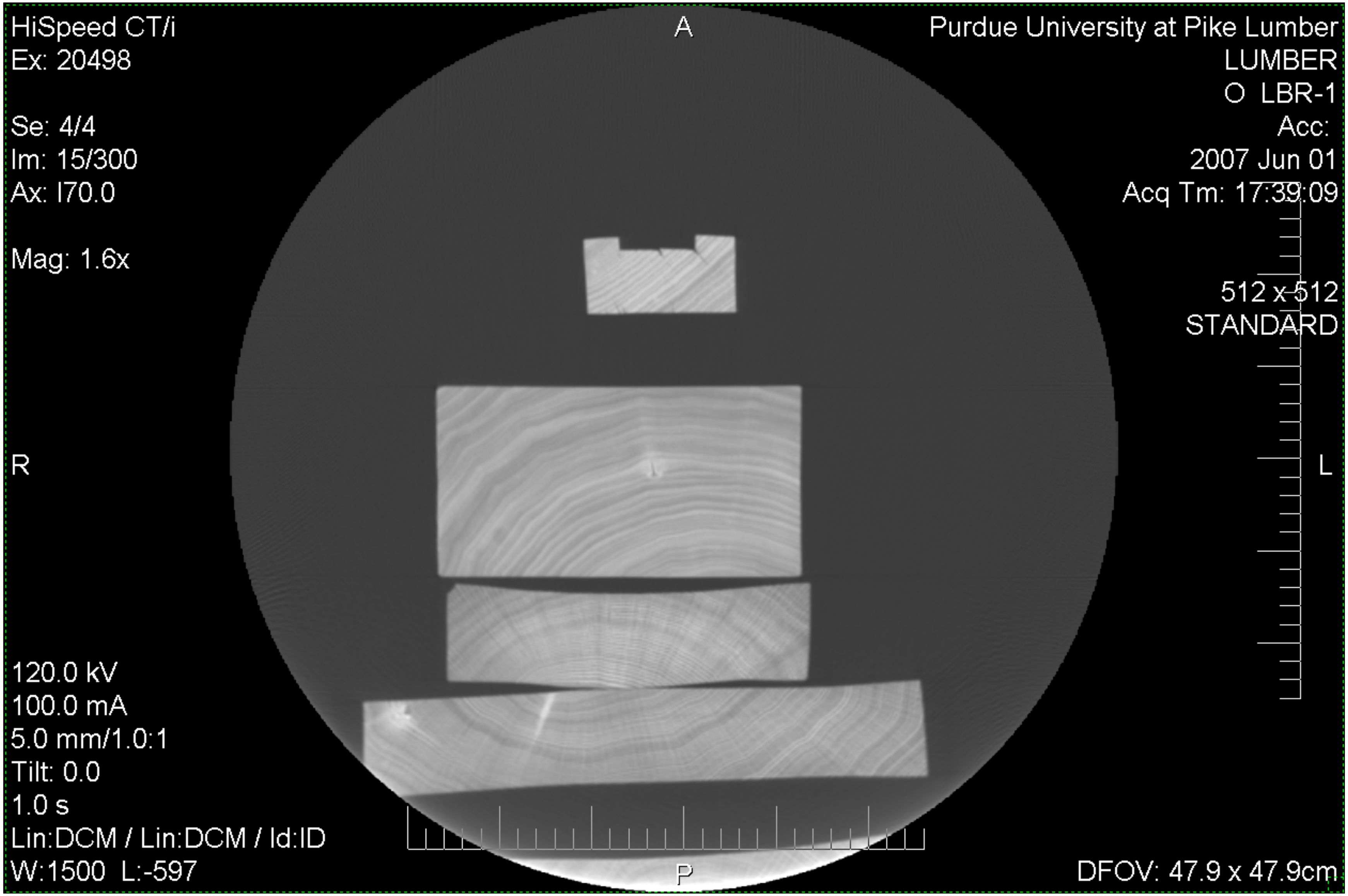
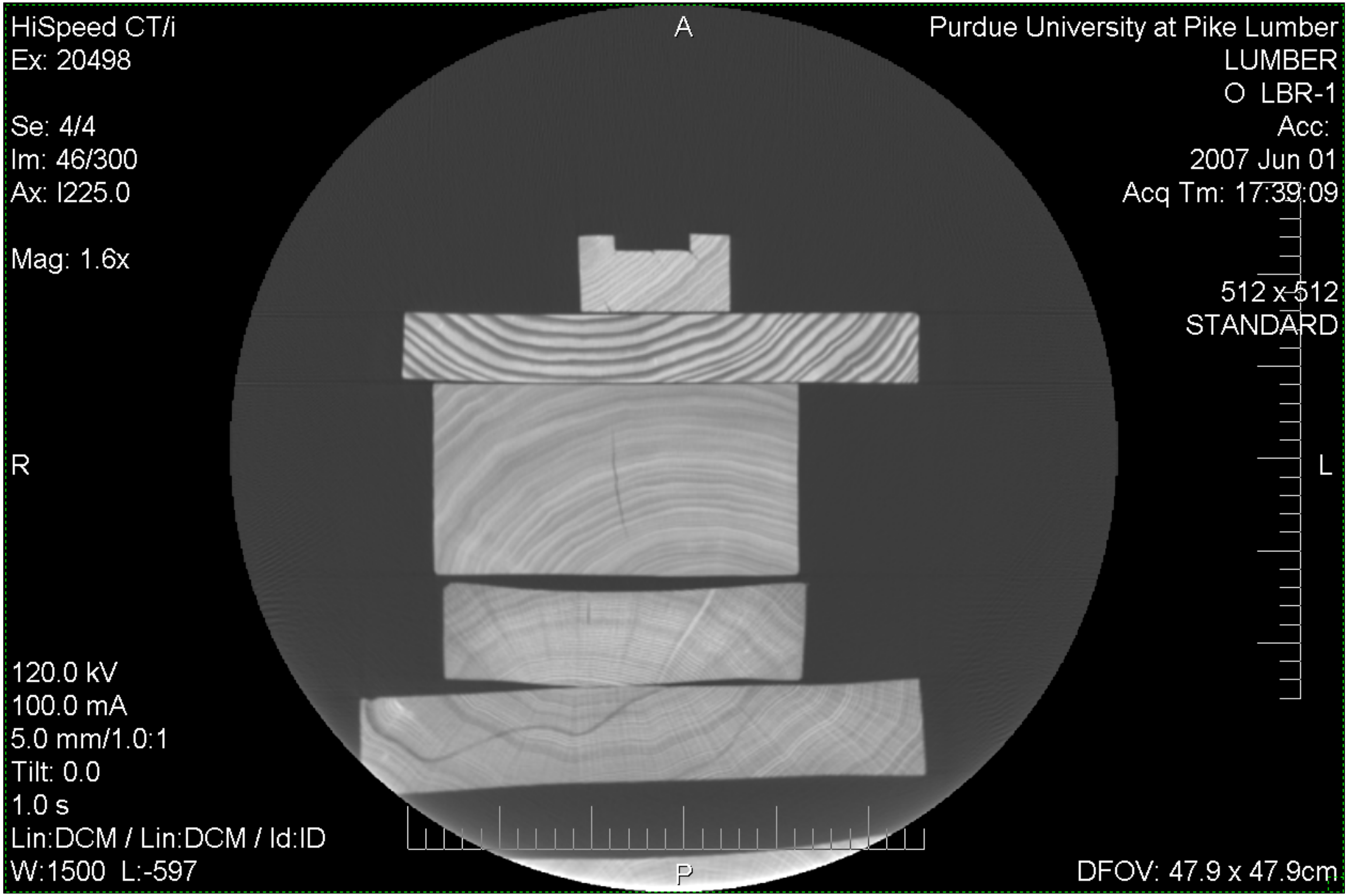
Hardwood Scanning Center



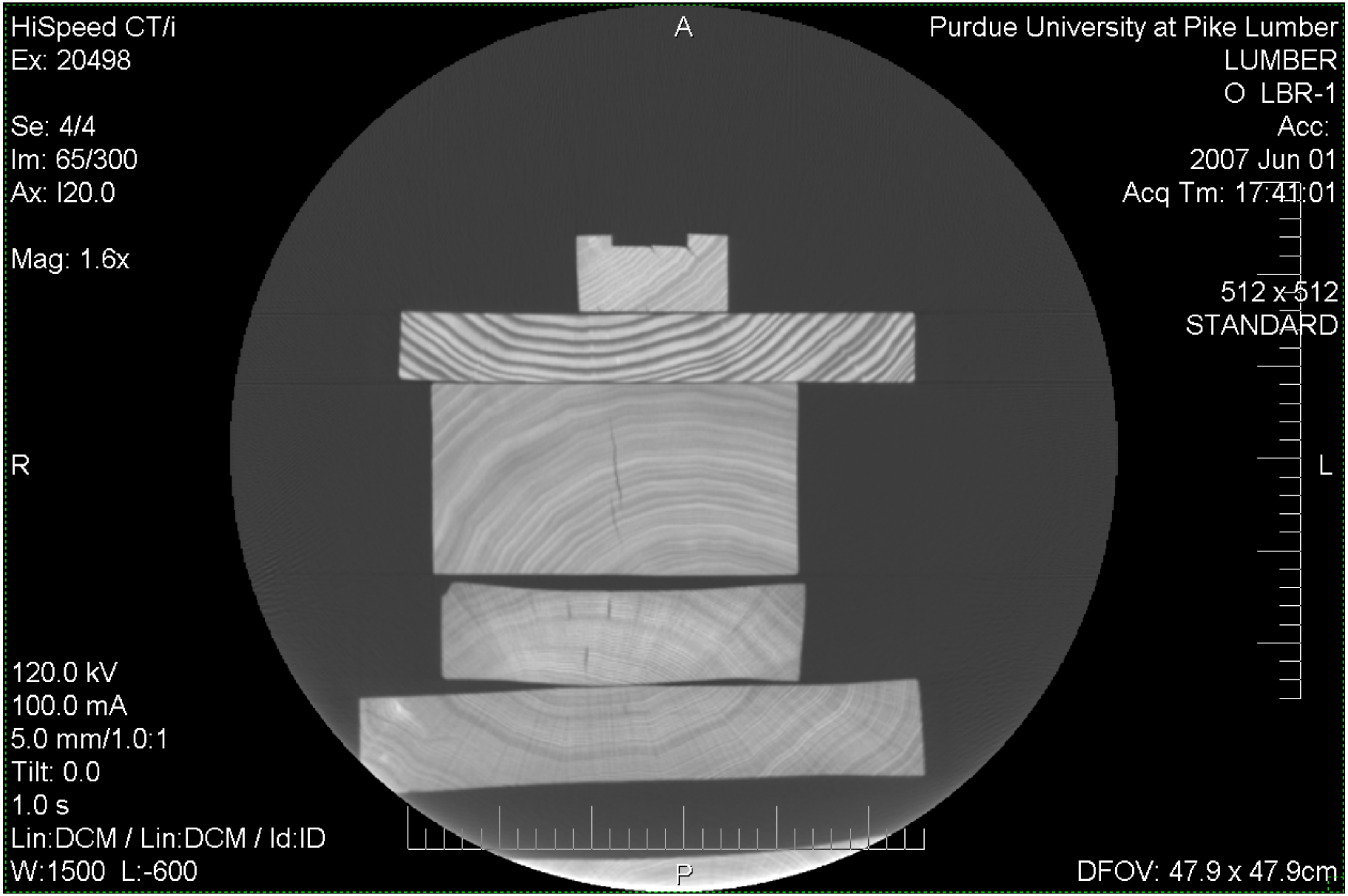
Pin Knot in Black Walnut Lumber

Hardwood Scanning Center



Powder Post Beatle in Red Oak Lumber

Hardwood Scanning Center

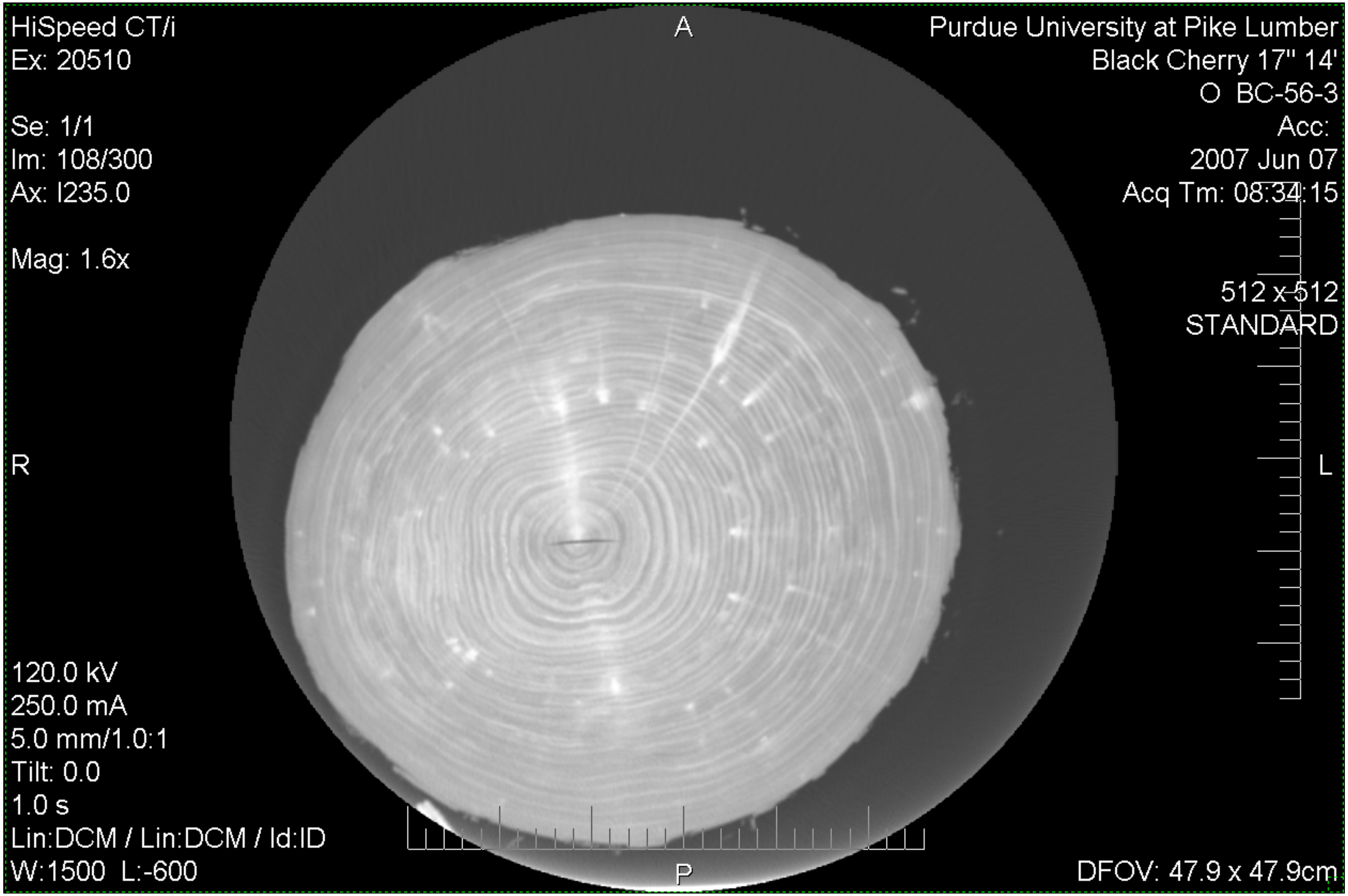


Honeycomb in Red Oak & Black Walnut Lumber

We can see…

The Unpredictable

Hardwood Scanning Center

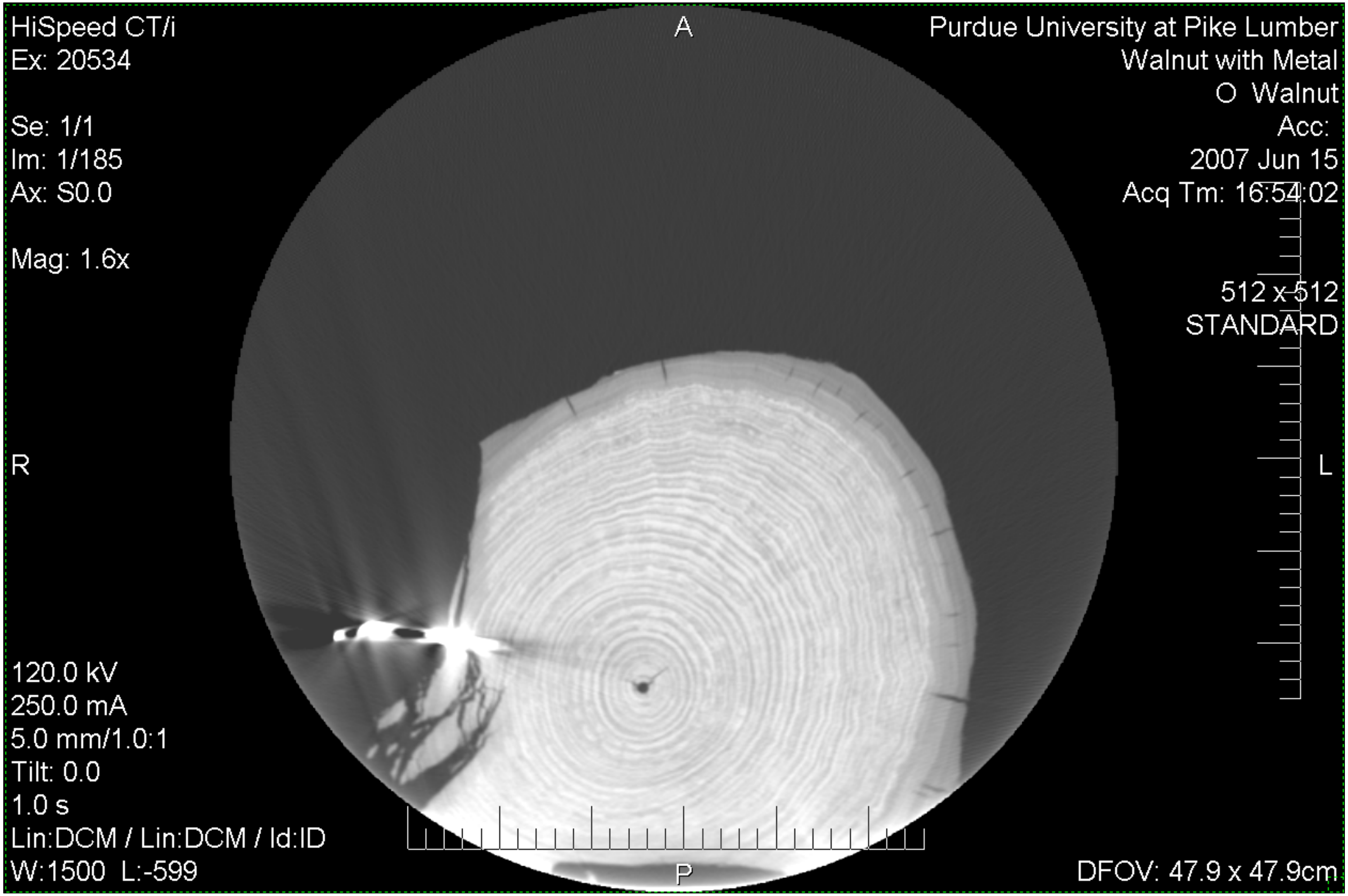


Gum in Black Cherry

Hardwood Scanning Center

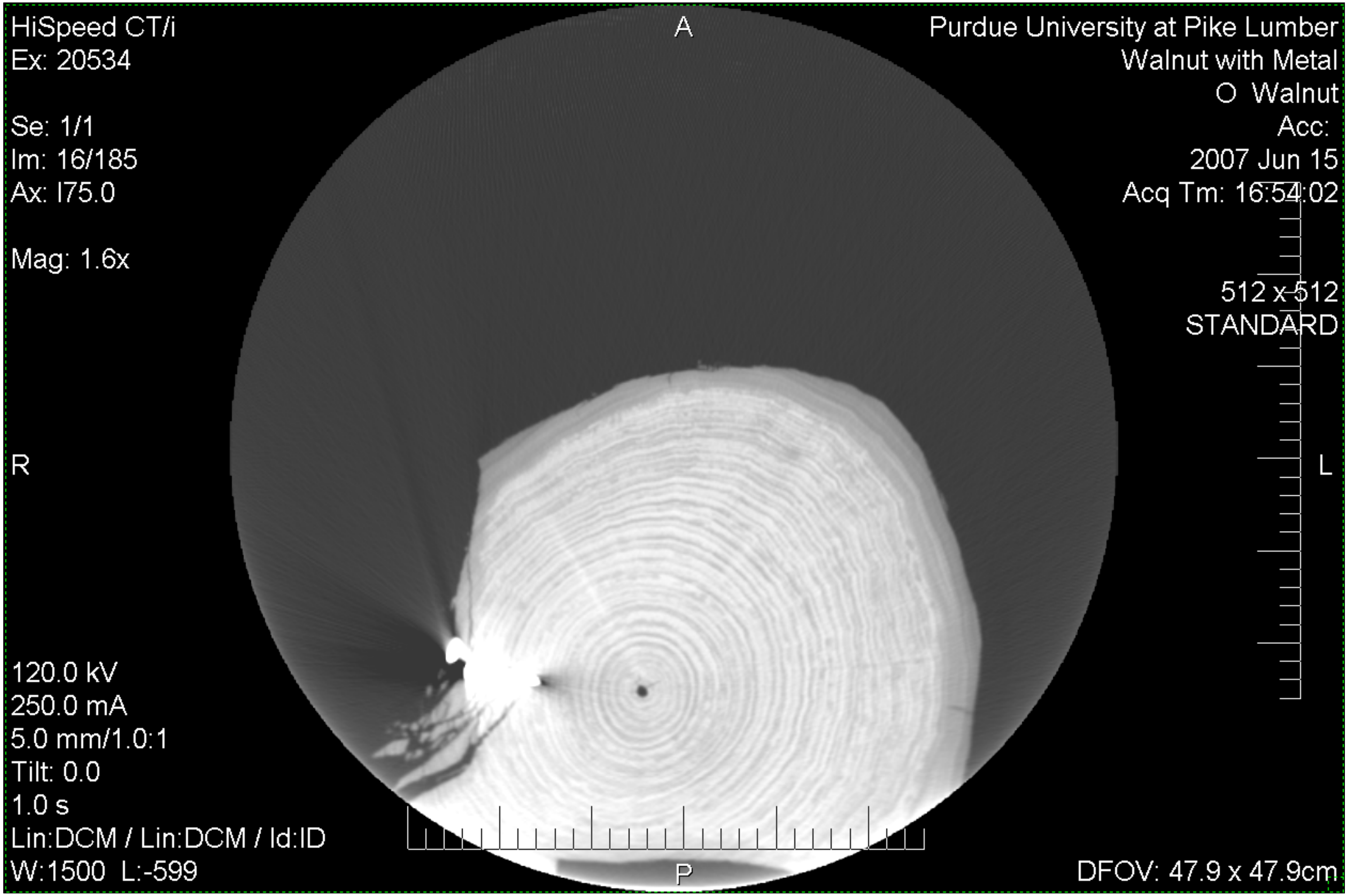
Bark Inclusion in Hard Maple

Hardwood Scanning Center



Nail in Black Walnut

Hardwood Scanning Center



Nail in Black Walnut

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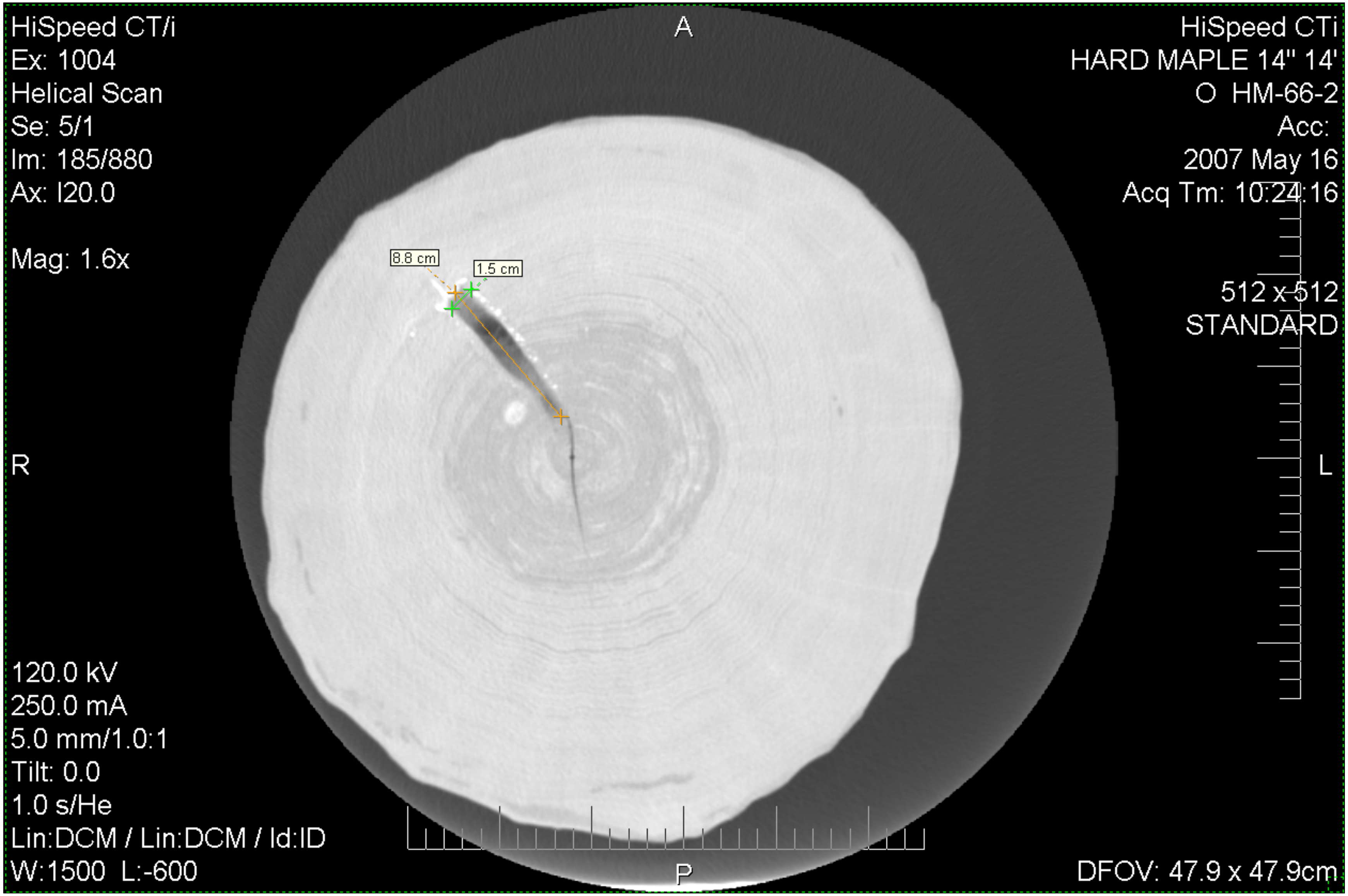
Tap Hole in Hard Maple

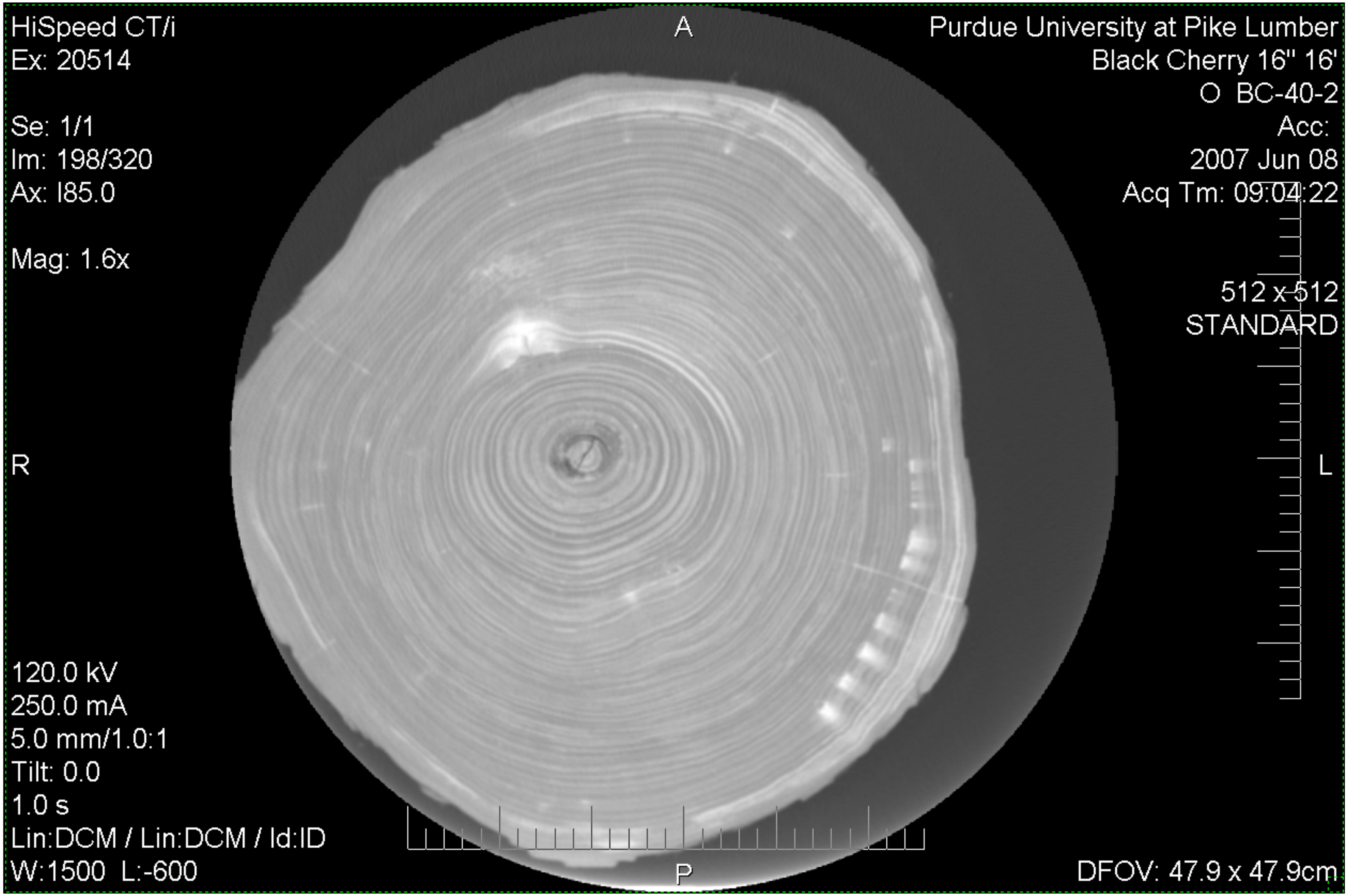
Hardwood Scanning Center



Tap Whole in Hard Maple

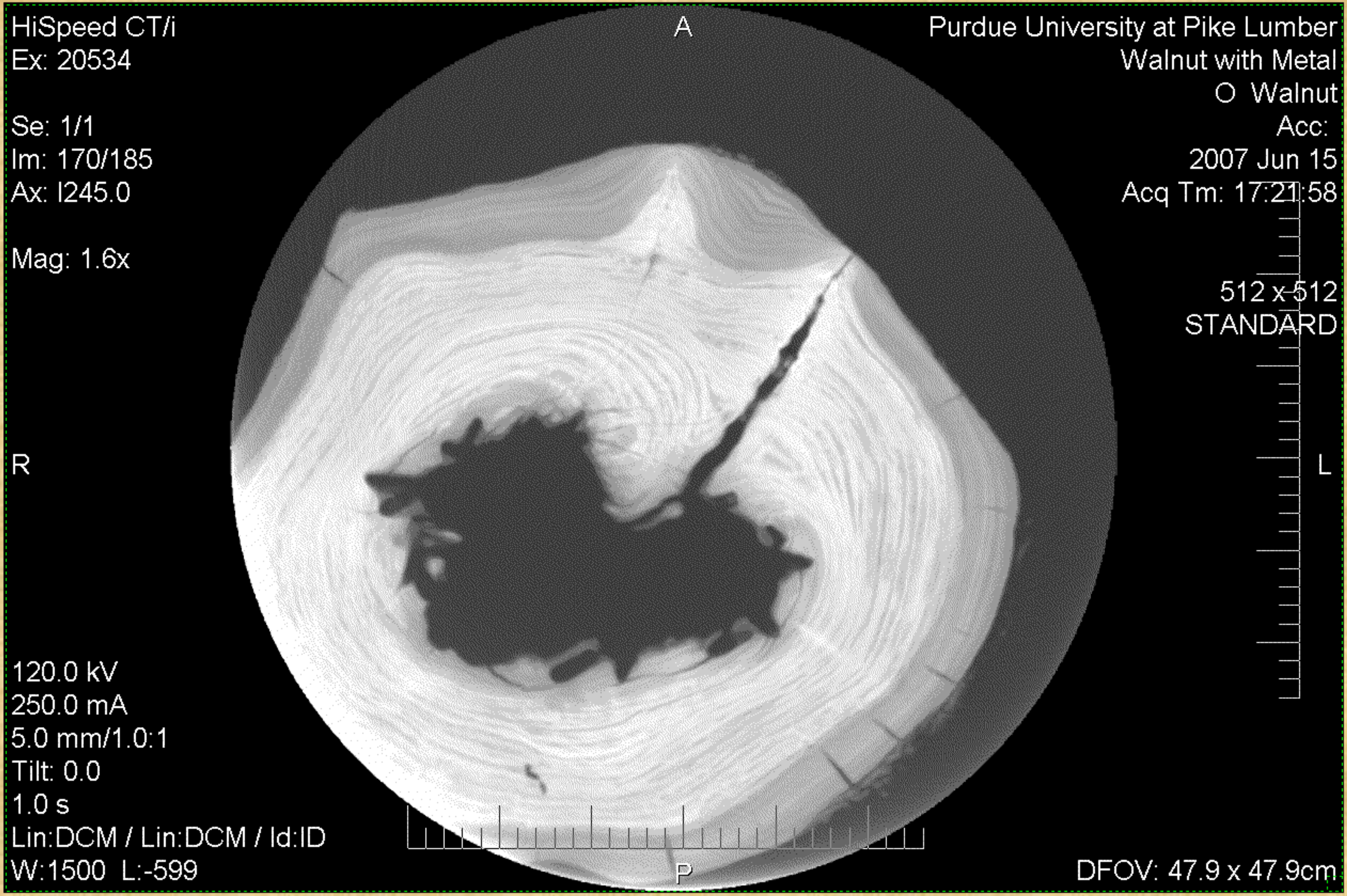
PURDUE UNIVERSITY

Hardwood Scanning Center



? In Black Cherry

Hardwood Scanning Center

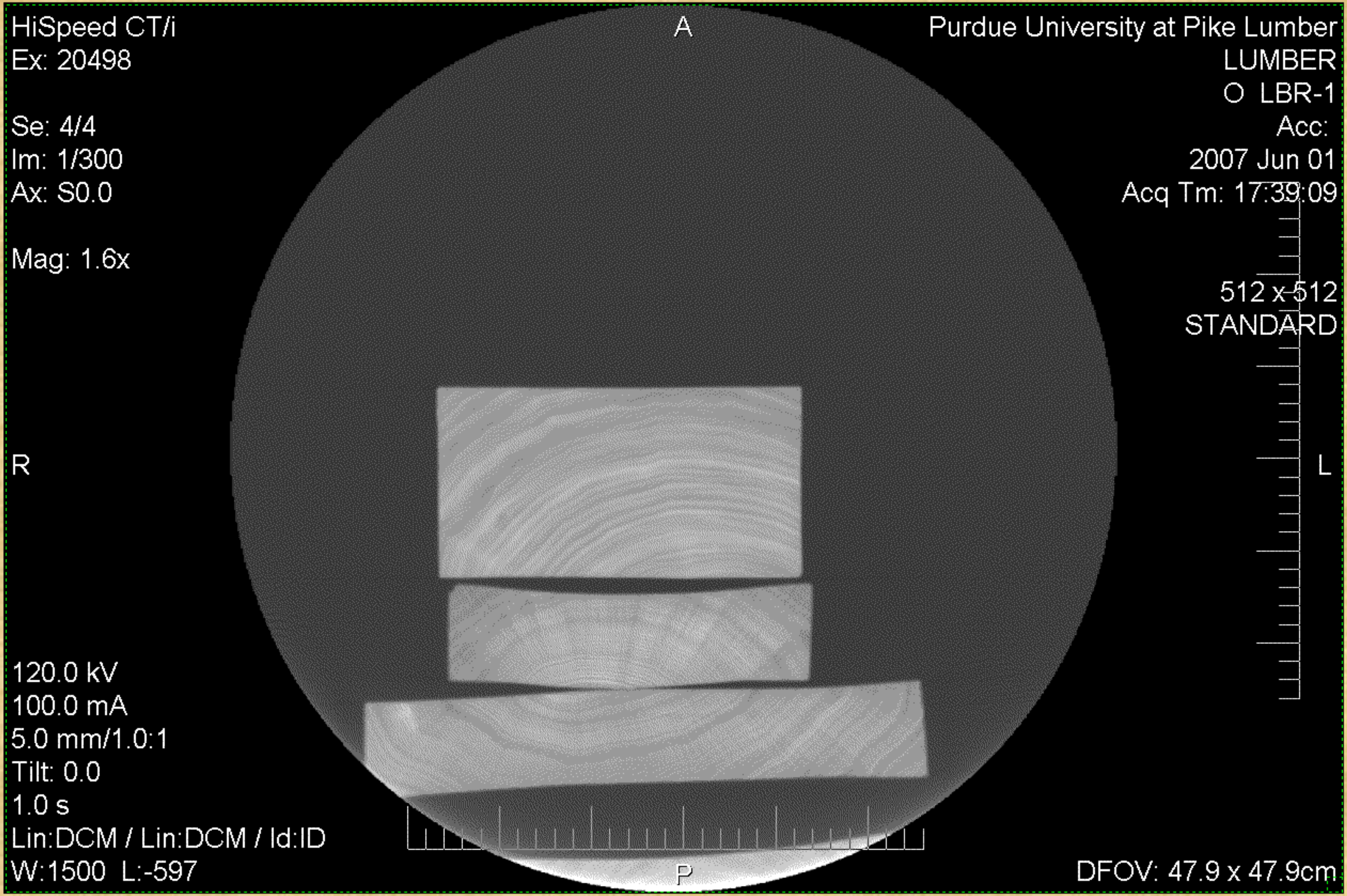


Metal in Black Walnut

Hardwood Scanning Center

The Full Extent of Grubs in Red Oak

Hardwood Scanning Center



Lumber

Random

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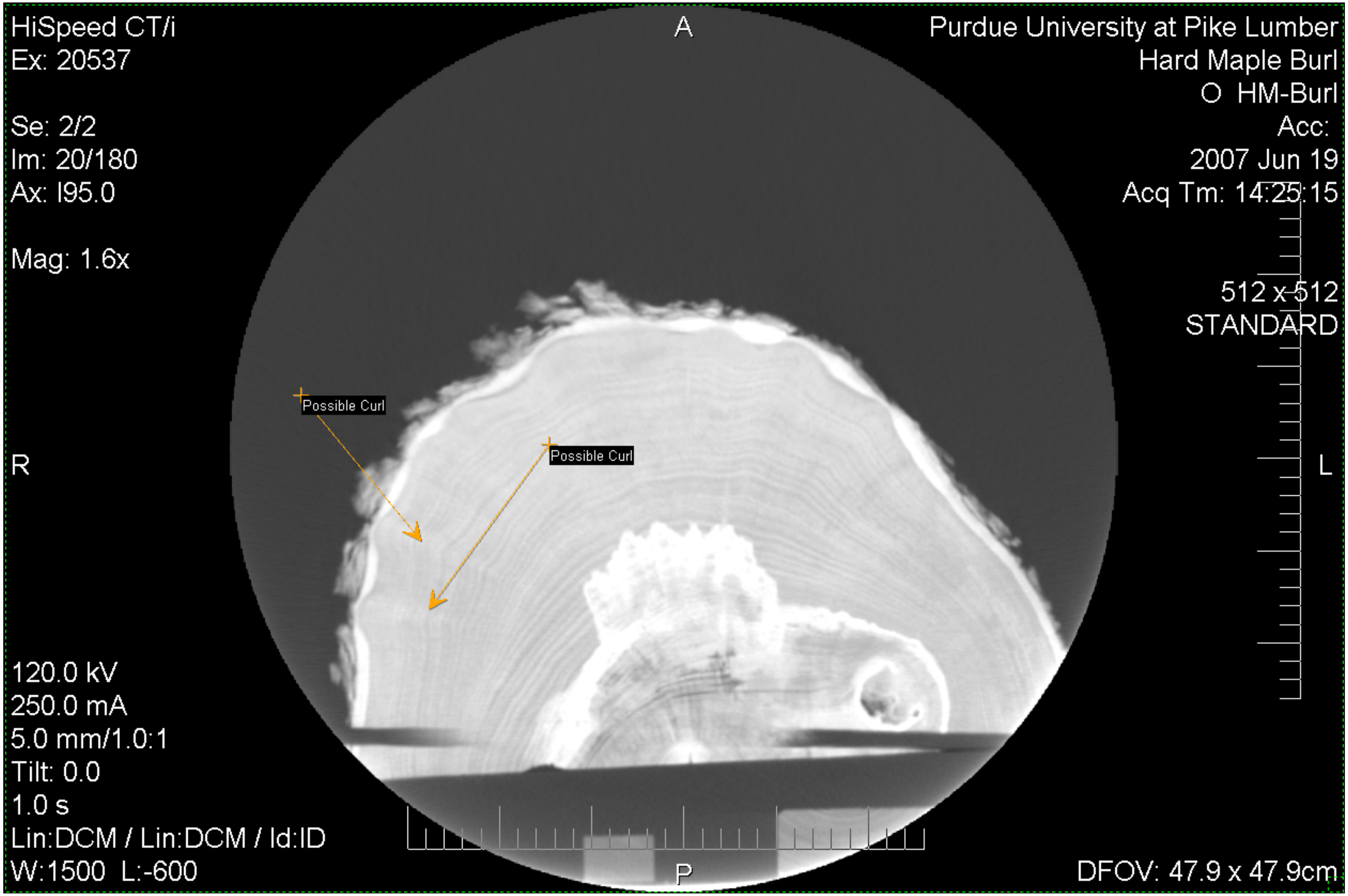
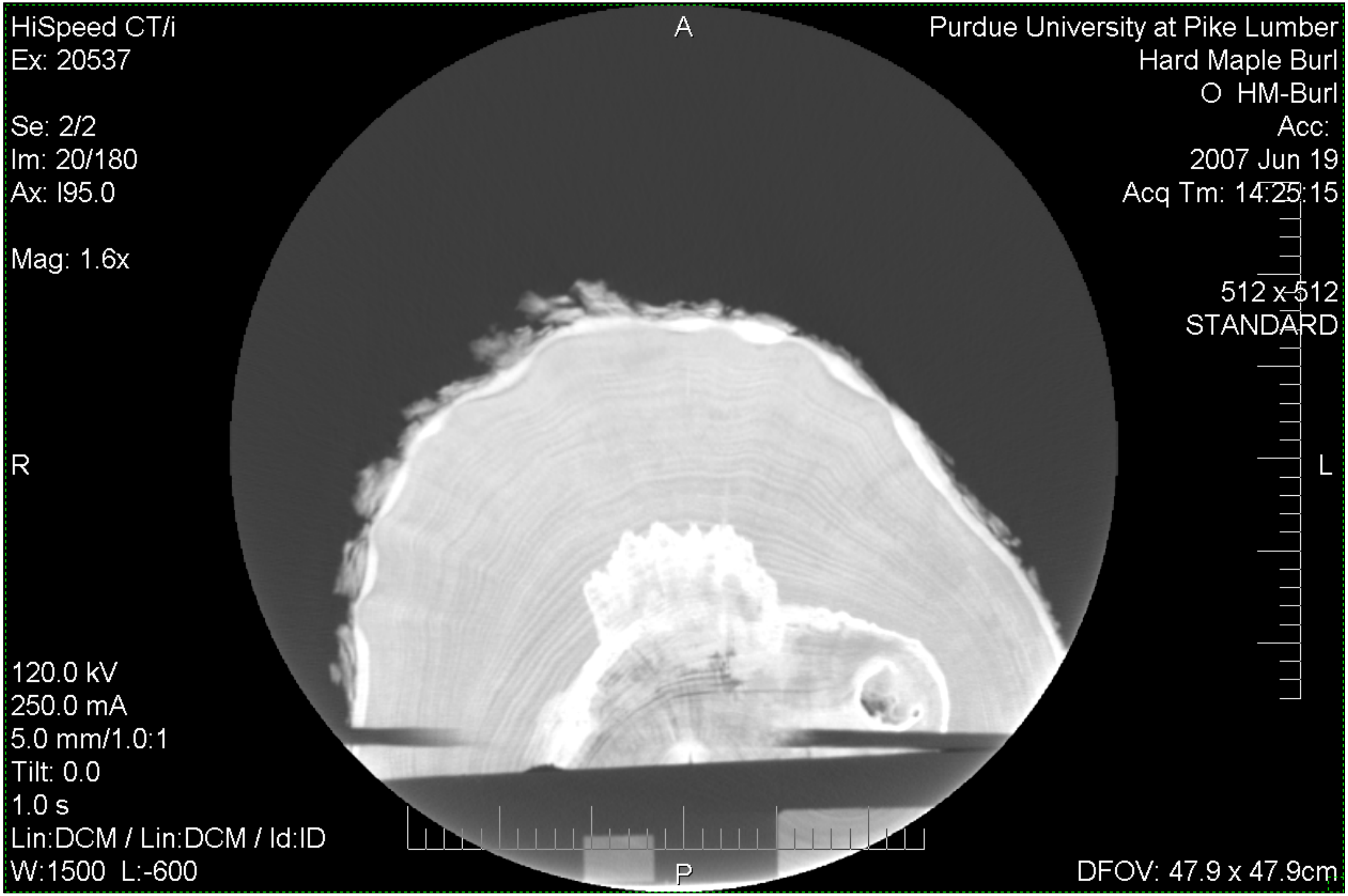
Hardwood Scanning Center



Curl

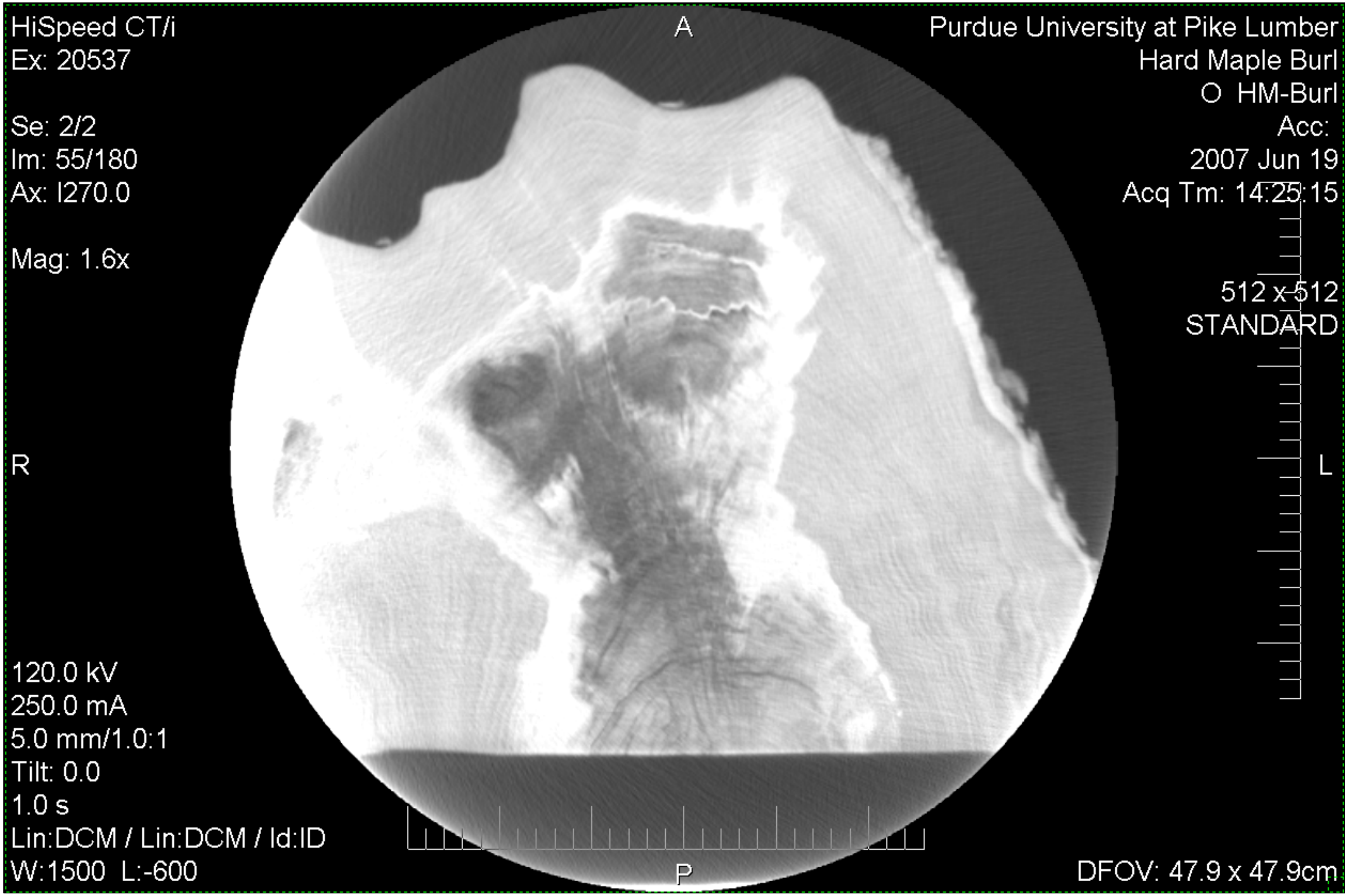
Hardwood Scanning Center



Curl

Purdue University

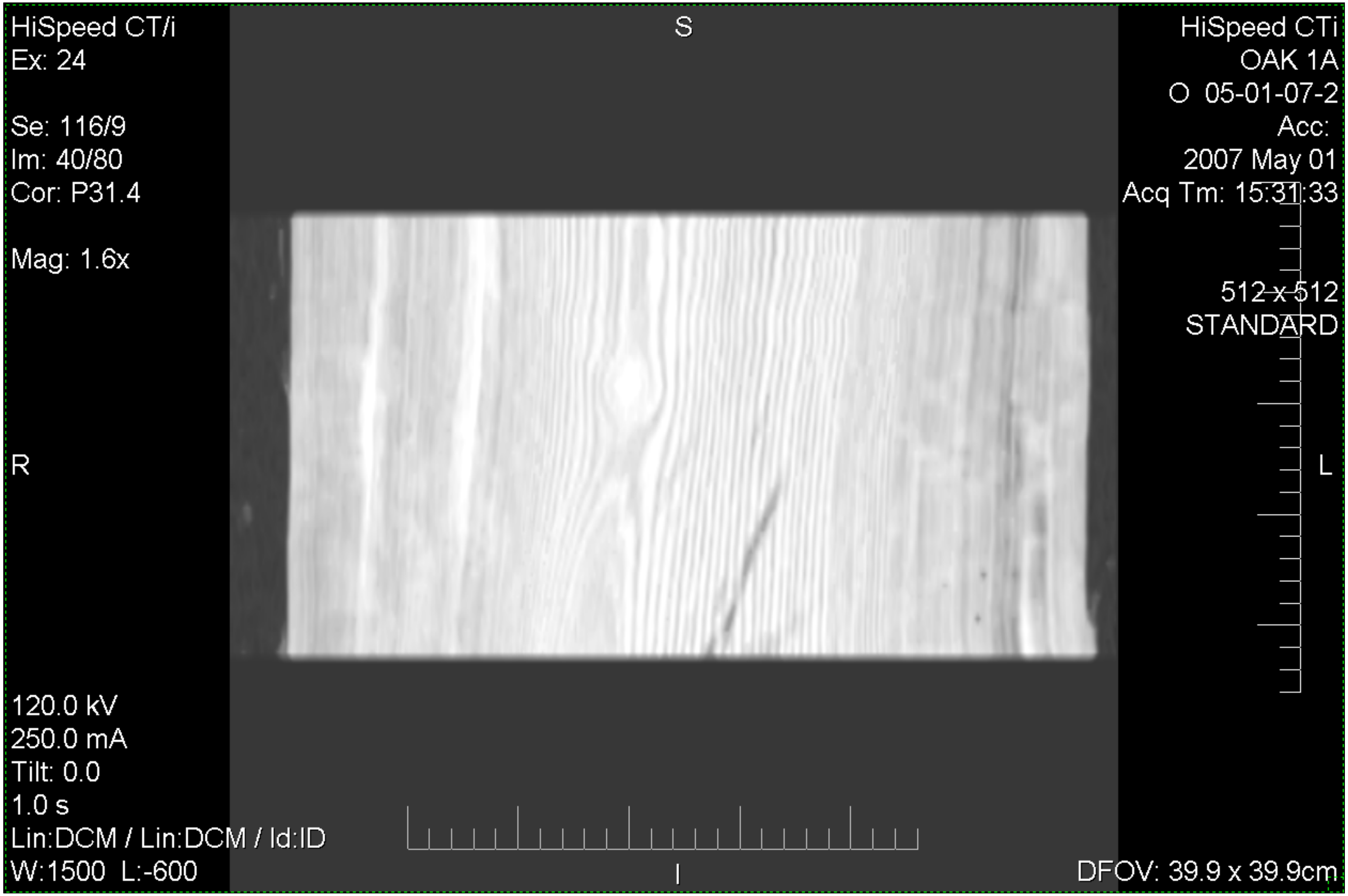
Hardwood Scanning Center



Spalting

Purdue University

Hardwood Scanning Center



Oak Board

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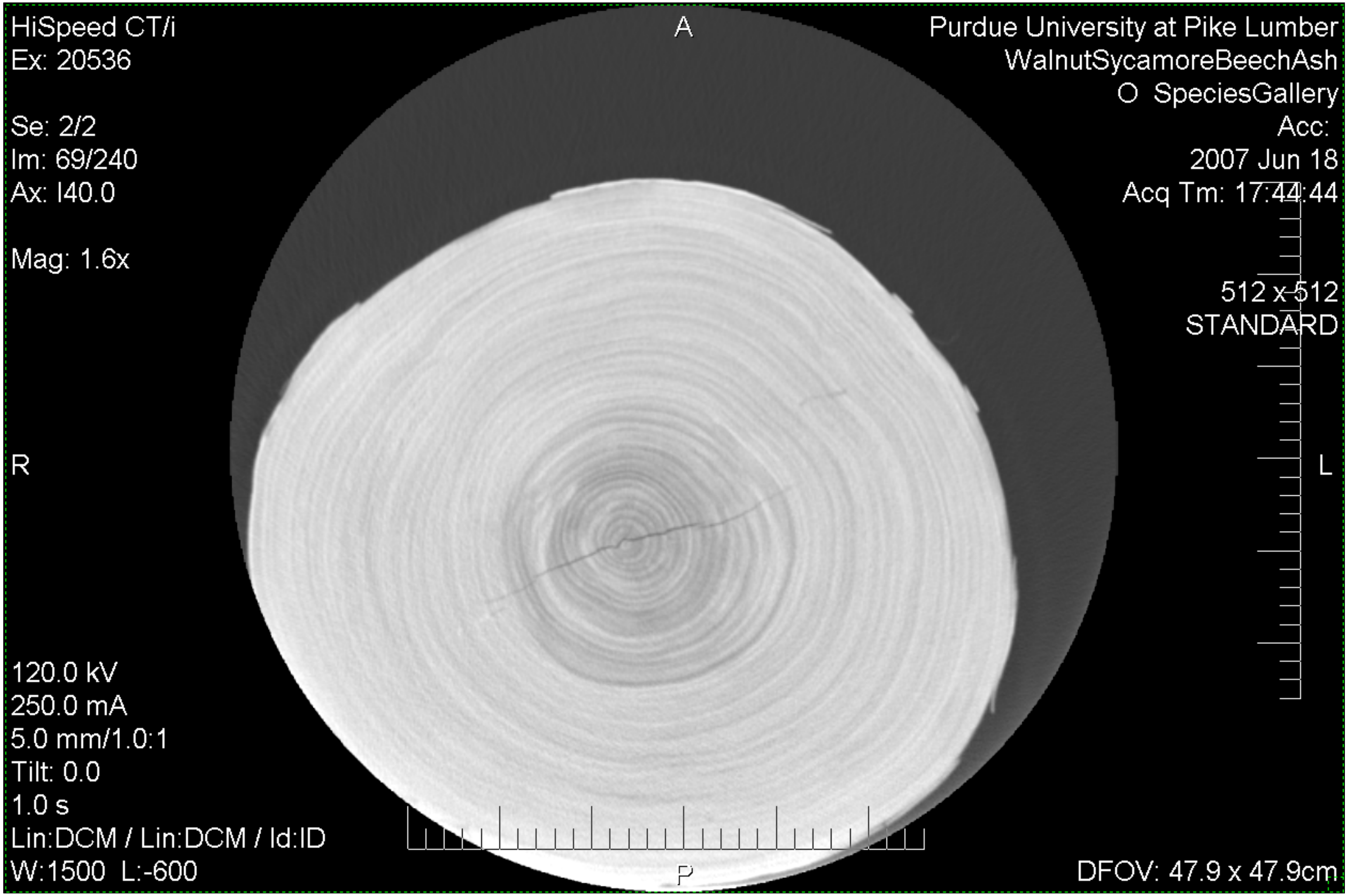
Hardwood Scanning Center



Sycamore

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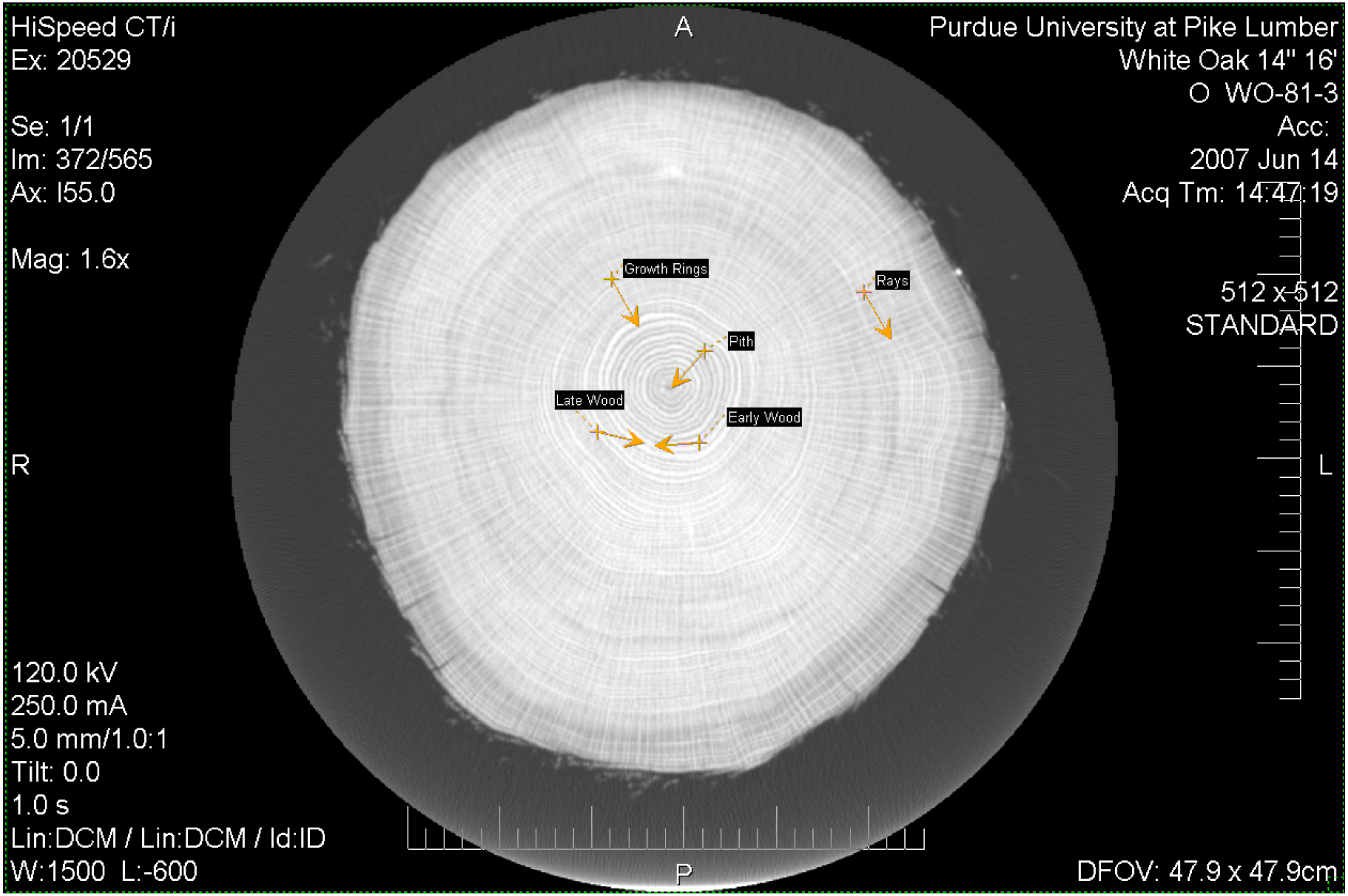
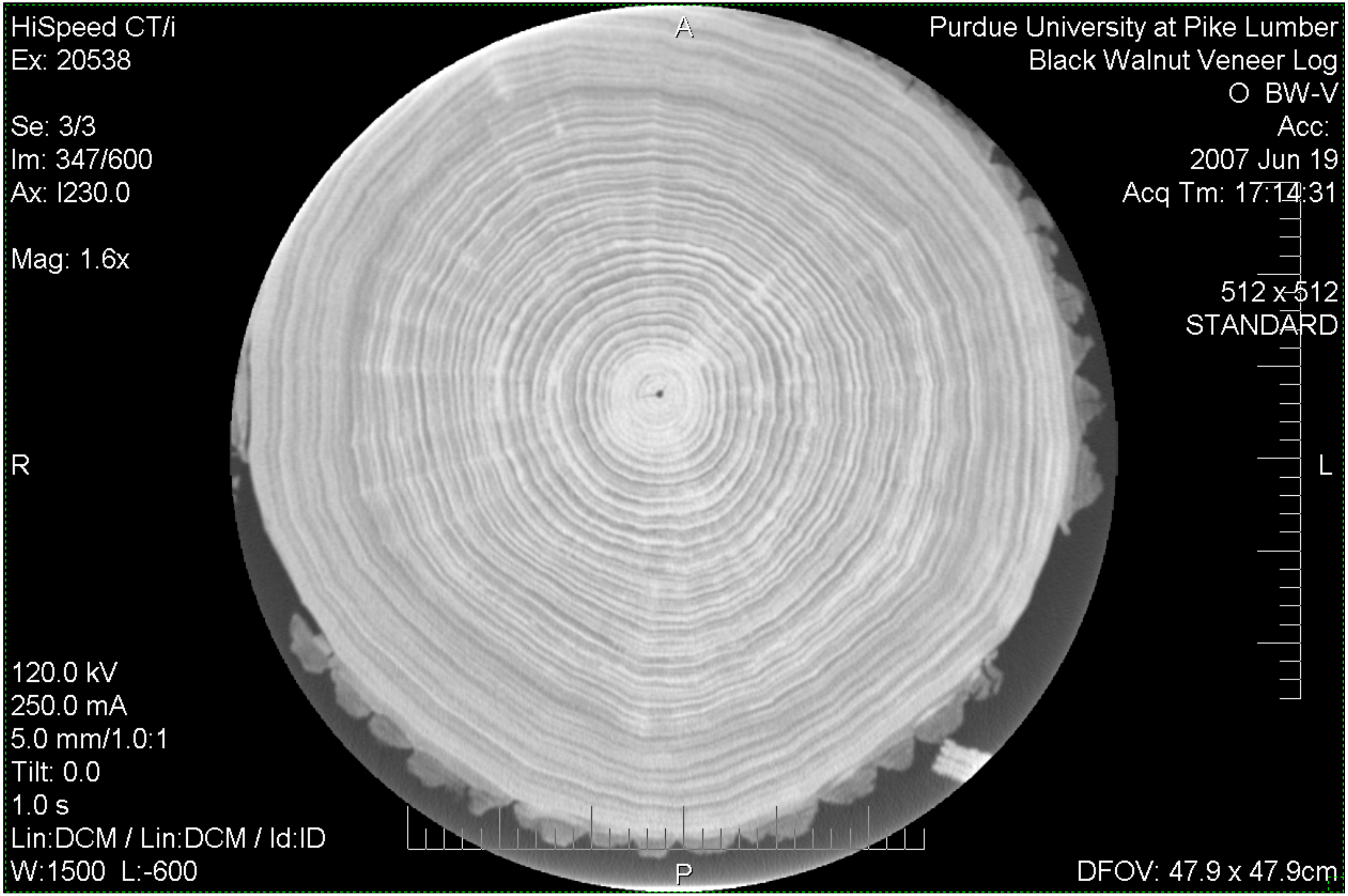
Hardwood Scanning Center



Features

Hardwood Scanning Center



Black Walnut

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Forestry & Natural Resources

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Innovations in Wood Processing

Rado Gazo

March 2013

San Jose, Costa Rica

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(logging, sawmills, veneer, plywood, etc.)


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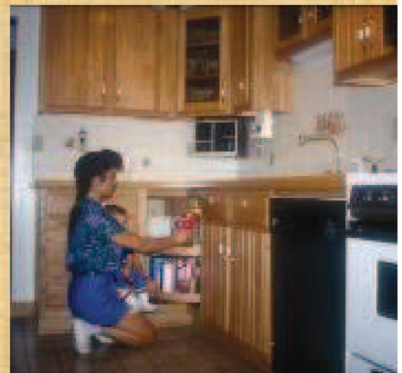

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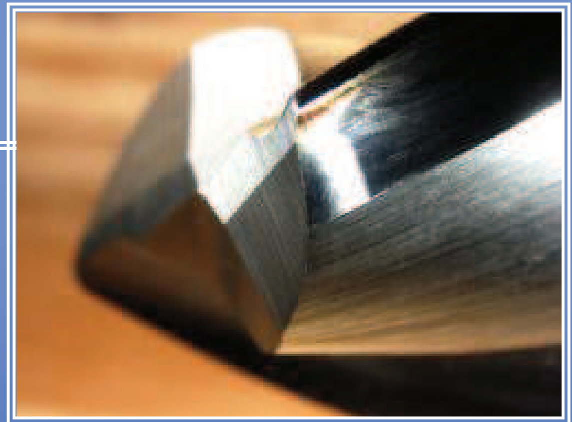
Primary/Secondary Wood Processing

Example: Cryogenic Treatment of Tools

Increased Tool Life through the Application of Refrigerated Air and Cryogenic Treatment when Machining Medium Density Fiberboard



Rado Gazo, Judith Gisip, and Harold A. Stewart
Wood Research Laboratory
Purdue University

Las Vegas, July 2005

Introduction

- In machining processes, high temperature is generated at the tool cutting edge, thus accelerating the wear on tools

- In metal cutting, tool wear is reduced with liquid coolant

- The hygroscopic nature of wood prevents the application of liquid coolant during the machining of wood and wood-based composites

- Thus, reducing the high temperature during cutting with refrigerated air may reduce tool wear when machining medium density fiberboard (MDF)

Introduction

• Cryogenic treatment is a one-time, permanent treatment that affects the entire tool structure

• During the treatment, the tools' temperature is gradually reduced in an airtight refrigeration chamber to below -300°F (-149°C), and is maintained for more than 20 hours before heated back to room temperature

• Cryogenic treated material may also require a subsequent heat treatment at 300°F to relieve stresses

• A few studies have been done to determine the effect of cryogenic treatment on the tool when cutting MDF (Stewart 2004)

Objective

To determine the effects of cryogenic treatment and refrigerated air on tool wear when cutting MDF with solid tungsten carbide tools

Methodology

Materials:

•Six double-flute, solid tungsten carbide router bits

•Half-inch (6.35 mm) diameter

•Tools randomly divided into two groups of three

•Group 1: Untreated

•Group 2: Cryogenically treated

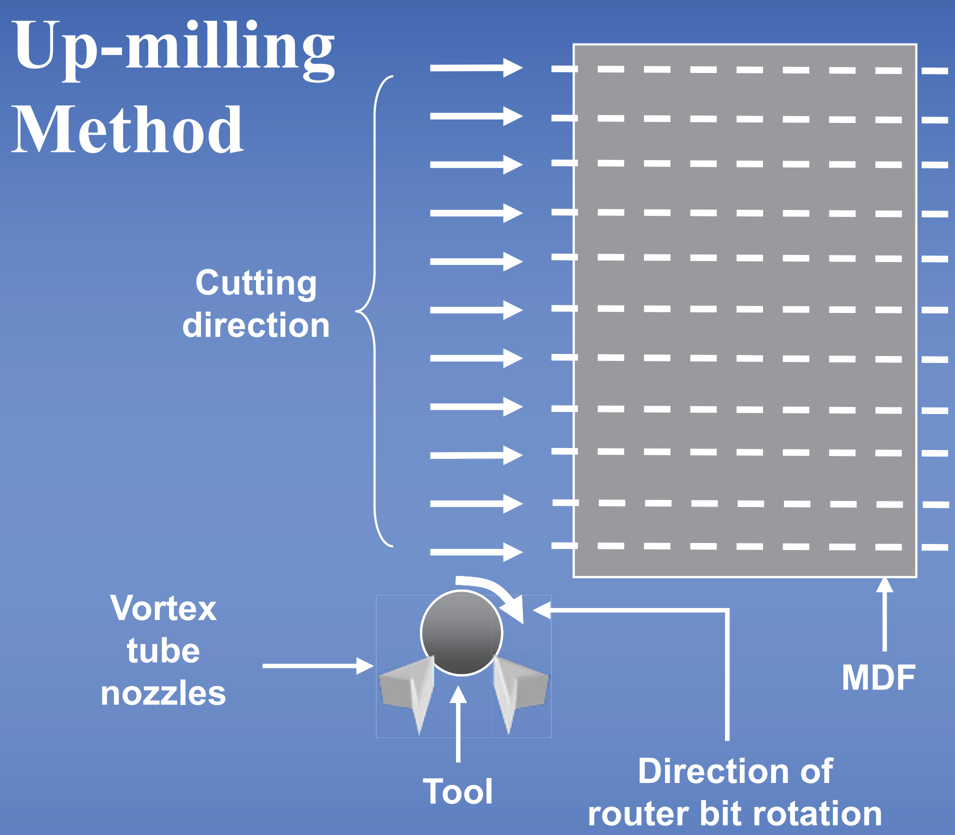
•22 1/2 MDF sheets cut by each tool (Premier grade)

•Length: 97” (2.46 m)

•Width: 49” (1.24 m)

•Thickness: ¾” (19.05 mm)

Methodology



- 360 complete passes/sheet
- 166,000 m (103 miles) length of cut per flute
- ¼” (6.35 mm) depth of cut

Tool moves at:

- 16,000 revolutions per minute
- Feed speed 384 inches per minute (9.75 meters per minute)

$$U = \text{Feed speed} = \frac{Sz \times Z \times N}{12}$$

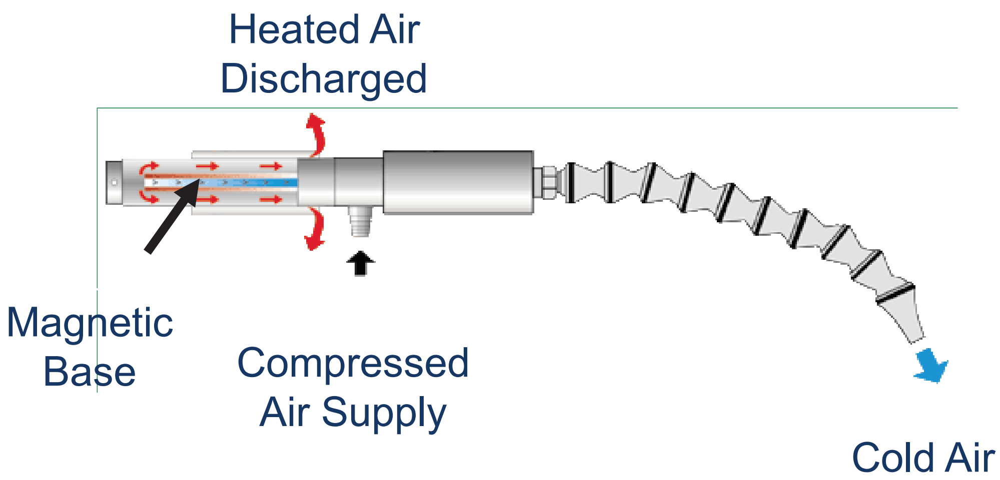
N = RPM = 16,000;

Z = # knives = 2

Sz = cut per tooth = 0.012 to 0.015 inches

How the vortex tube works

Incoming Air 90°F
Cold Gun -50°F
Resulting Temp. 40°F (4.4°C)

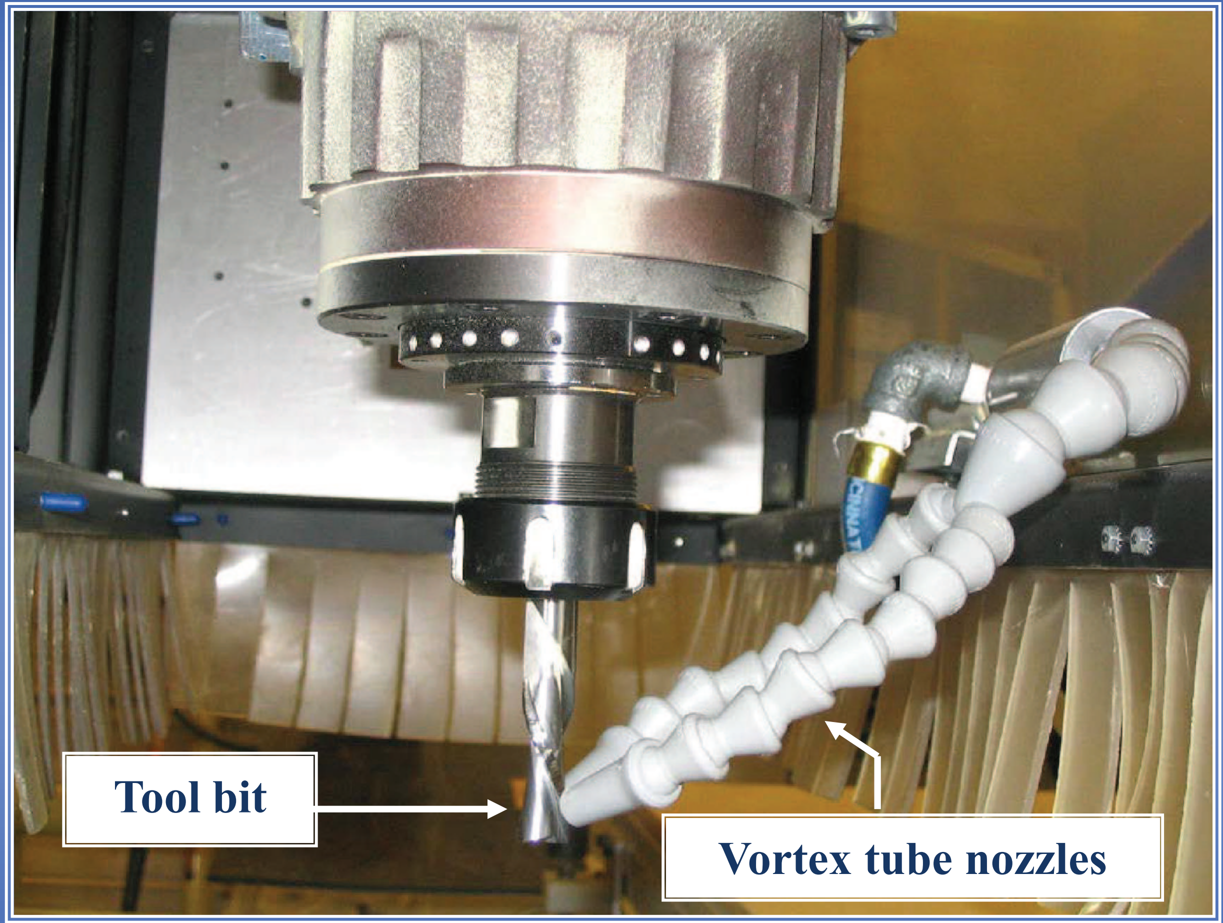


The cold gun reduces temperature of incoming compressed air by about 50º Fahrenheit

Incoming Air	90°F
Ice Bath	-20°F
<u>Cold Gun</u>	<u>-50°F</u>

Resulting Temp. 20°F (-6.7°C)

Methodology



Placement of vortex tube in relation to the router bit

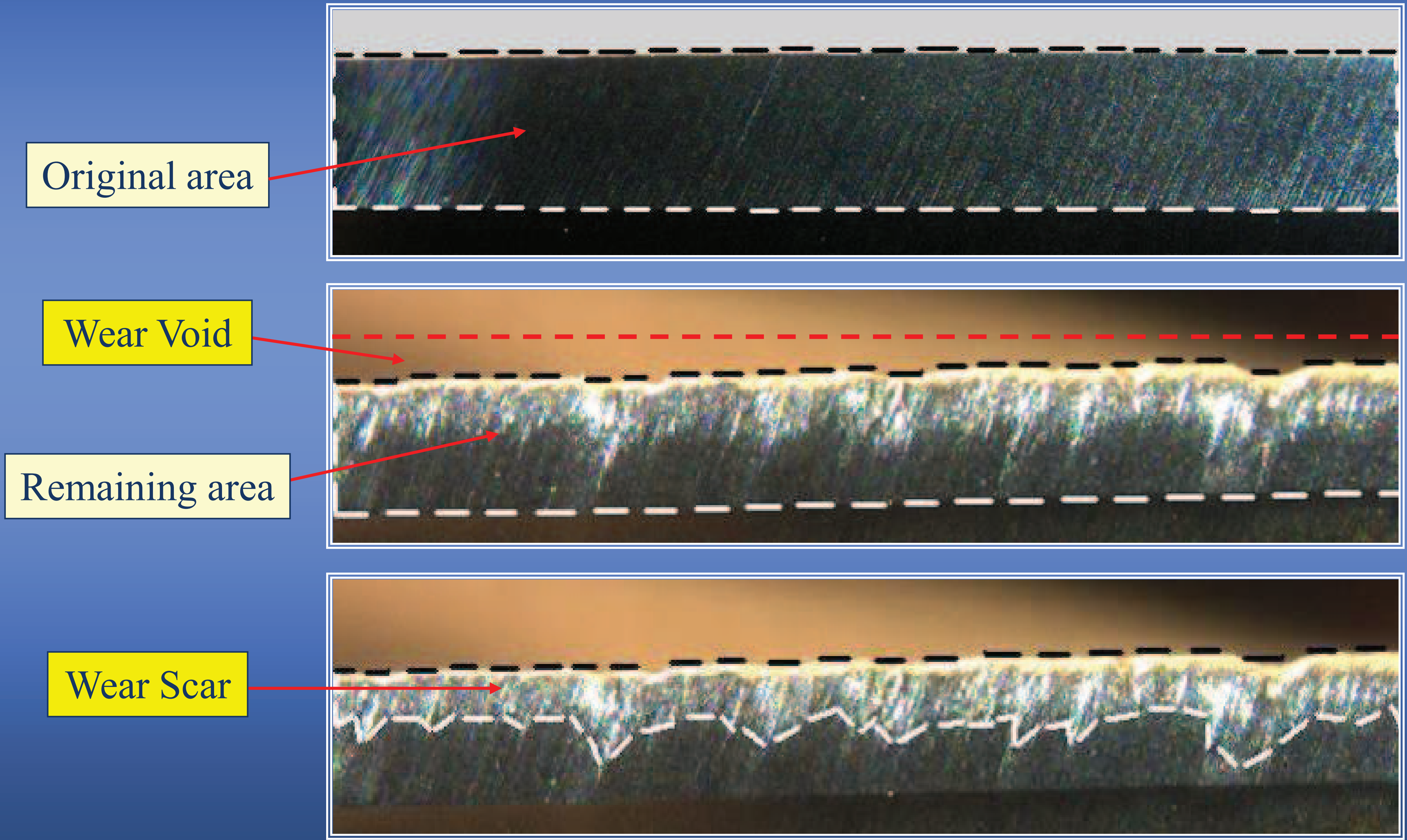
Methodology

• Power data (Amp, kW) were measured throughout the cutting process

•Sound level (dB) measurement

• A visual assessment of MDF edge surface by a panel of five judges

Methodology



Results and Discussion
•Untreated tools

70°F (21°C) **40°F (4.4°C)** **20°F (-6.7°C)**



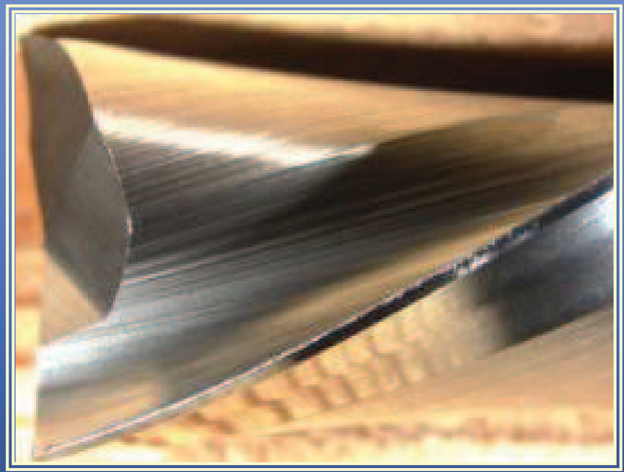



Results and Discussion

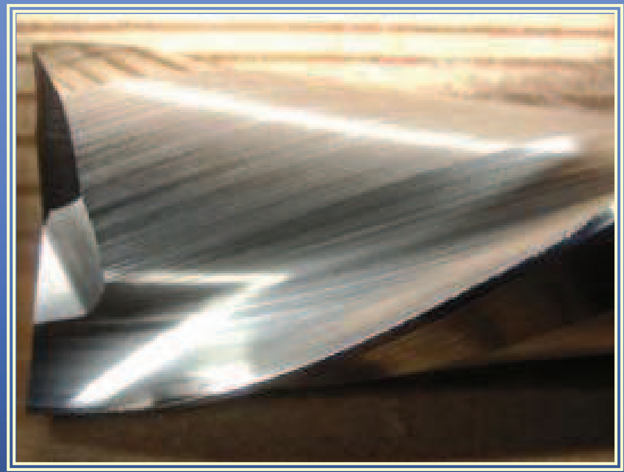
•Cryogenically treated tools

70°F (21°C)

40°F (4.4°C)



20°F (-6.7°C)



Results and Discussion

Effect of cryogenic treatment at 70°F (21°C)

Table 1. – **Wear void, wear scar and total wear as a percentage of the original clearance face area. Superscript letters indicate the significance of each temperature tested at 0.05 significance level.**

	Temperature	Wear void $p = 0.006$*	Wear scar $p = <.0001$*	Total wear $p = <.0001$*
	(°C)	(%)	(%)	(%)
Untreated	21.0	32.07^{a}	44.09^{a}	76.16^{a}
Treated	21.0	20.71^{b}	25.31^{b}	46.02^{b}

*These p-values correspond to H_0: No treatment effect

Statistical results were calculated with Two-way ANOVA

Results and Discussion

Effect of temperature on untreated tools

Table 2. **– Wear void, wear scar and total wear as a percentage of the original clearance face area. Superscript letters indicate the significance of each temperature tested at 0.05 significance level.**

Temperature	Wear void P-value = 0.225*	Wear scar P-value = 0.006*	Total wear P-value = 0.025*
(°C)	(%)	(%)	(%)
21.0	32.07[a]	44.09[a]	76.16[a]
4.4	25.39[a]	34.64[b]	60.03[b]
-6.7	25.68[a]	40.63[a]	66.31[b]

*These p-values correspond to H_0: No temperature effect.

Statistical results were calculated with Two-way ANOVA

Results and Discussion

Effect of temperature on cryogenically treated tools

Table 3. **–Wear void, wear scar and total wear as a percentage of the original clearance face area for cryogenically treated tools. Superscript letters indicate the significance of each temperature tested at 0.05 significance level.**

Temperature	Wear void $p = 0.225$*	Wear scar $p = 0.006$*	Total wear $p = 0.025$*
(°C)	(%)	(%)	(%)
21.0	20.71[a]	25.31[a]	46.02[a]
4.4	17.86[a]	23.41[b]	41.27[b]
-6.7	16.13[a]	18.96[a]	35.09[b]

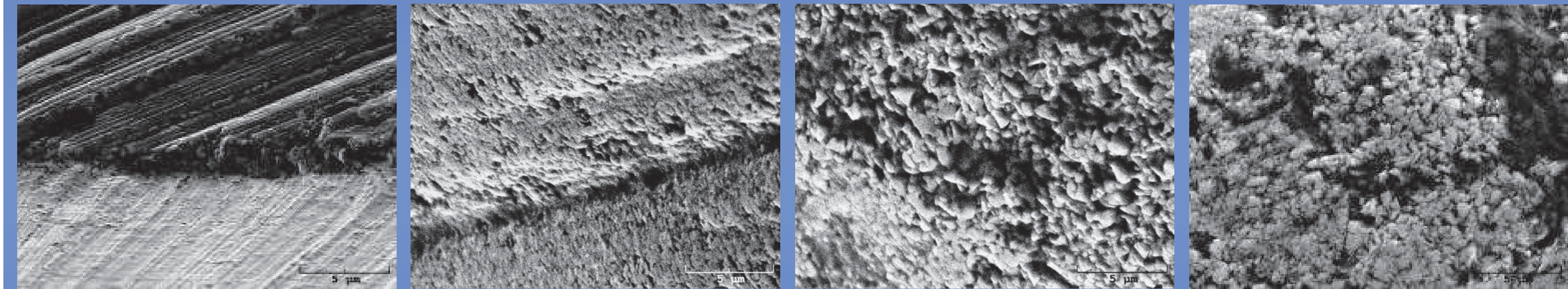
*These p-values correspond to H_0: No temperature effect

Statistical results were calculated with Two-way ANOVA

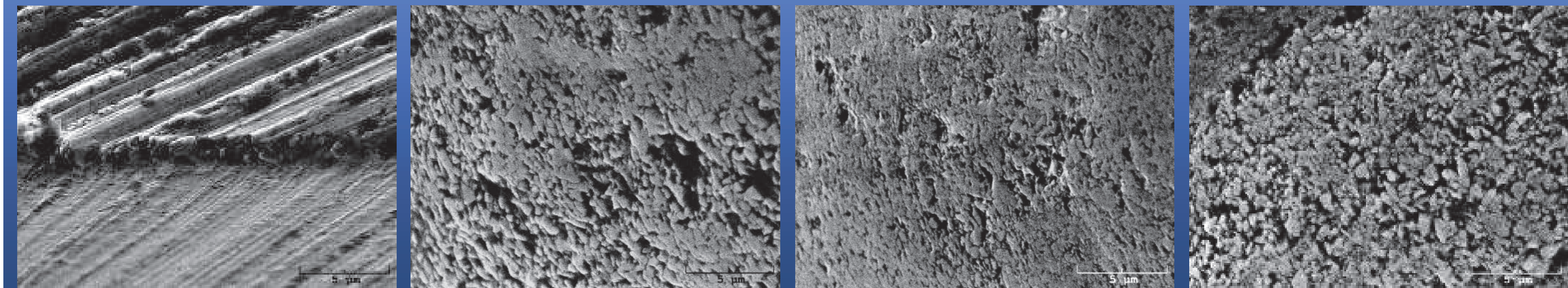
Tool Surface Microstructure (Magnification. 5400X)

Unused	70°F(21°C)	40°F(4.4°C)	20°F(-6.7°C)

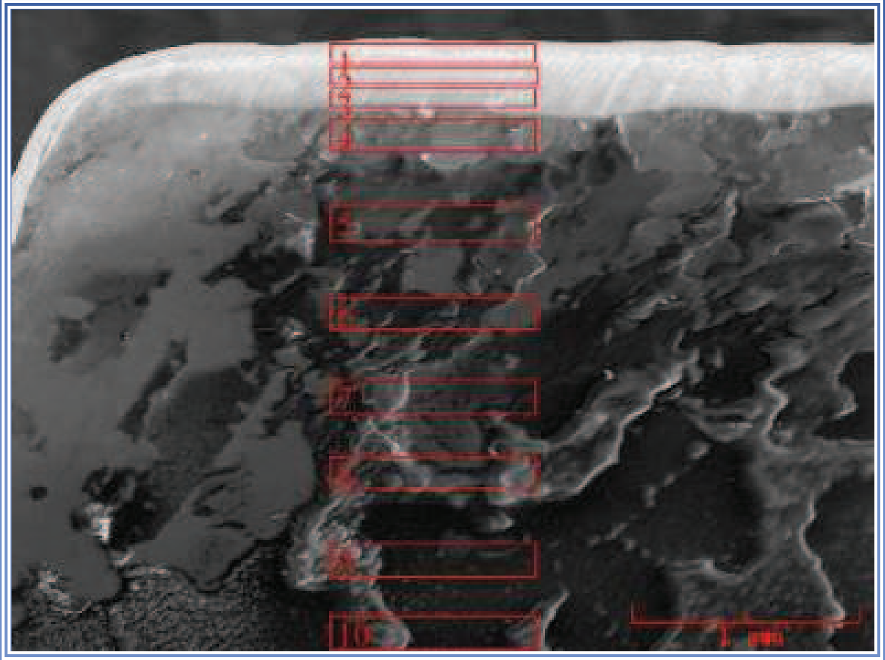
Untreated



Cryogenically treated



Results and Discussion - Energy-dispersive spectroscopy



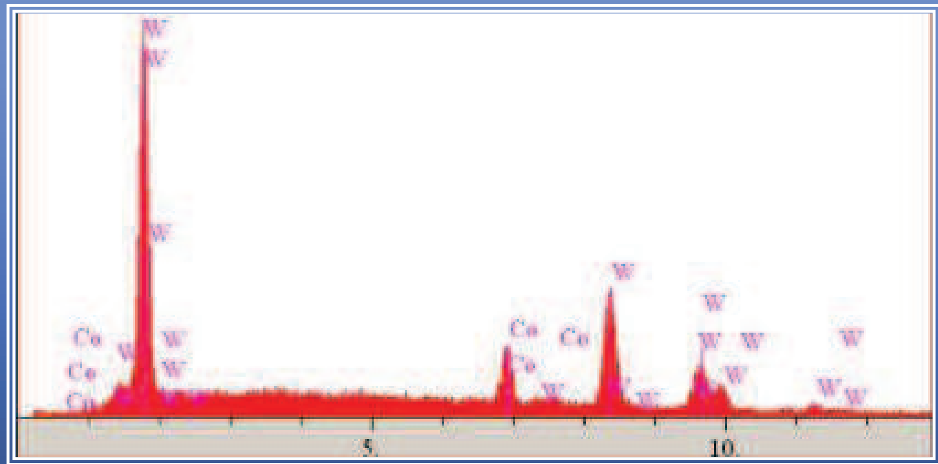
Element	1	2	3	4	5	6	7	8	9	10
	(wt. %)									
Nitrogen	0.16	0.6	0.2	0.5	0.6	1.15	0.57	2.29	3.76	0
Oxygen	0.05	0.19	0.18	0.52	0.26	0.71	0.52	1.16	1.09	5.6
Sodium	0.04	0.02	0.02	0.03	0.1	0.1	0.11	0.14	0.26	0.4
Phosphorus	0.62	0.07	0.14	0.02	0	0.6	0.26	0.35	0.77	1.59
Sulphur	0.92	0.46	0.51	0.1	0.28	0.17	0.21	1.8	0.85	2.85
Chlorine	0.05	0.07	0.05	0.15	0.23	0.43	0.12	0.94	0.82	2.87
Potasium	0.31	0.11	0.2	0.29	0.32	0.91	0.7	1.62	1.8	3.51
Calcium	0.98	0.5	0.46	0.28	0.36	0.45	0.32	1.4	1.84	4.28
Cobalt	6.2	7.54	6.92	7.61	8.83	8.68	8.22	7.94	8.96	8.79
Tungsten	90.68	90.45	91.33	90.51	89.02	86.82	88.99	82.37	79.86	70.11

P, K and Ca – ash constituents of wood

N, O – atmosphere, glue catalyst

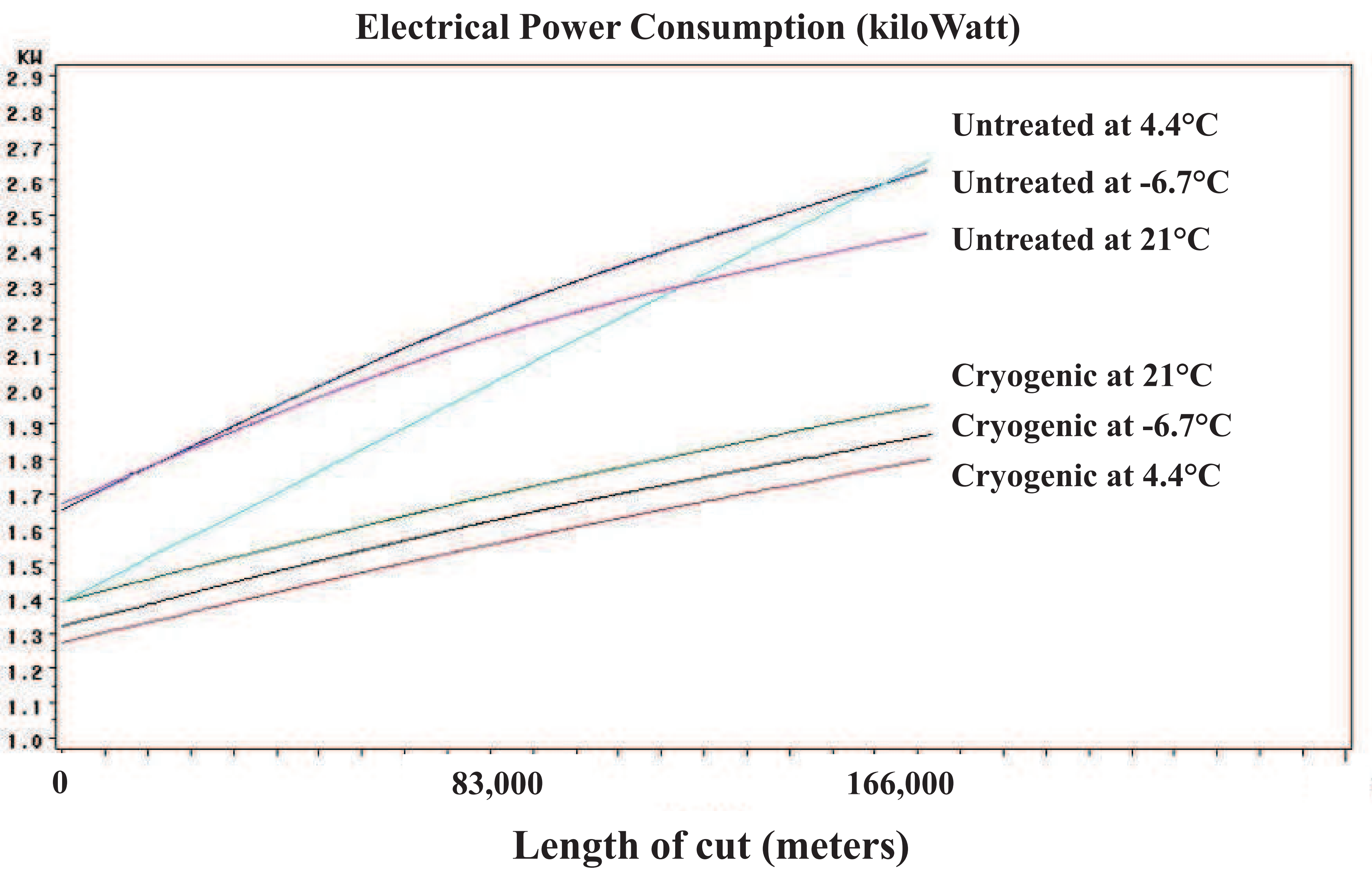
S – glue catalyst, wood

Cl, Na – adhesive extender, catalyst

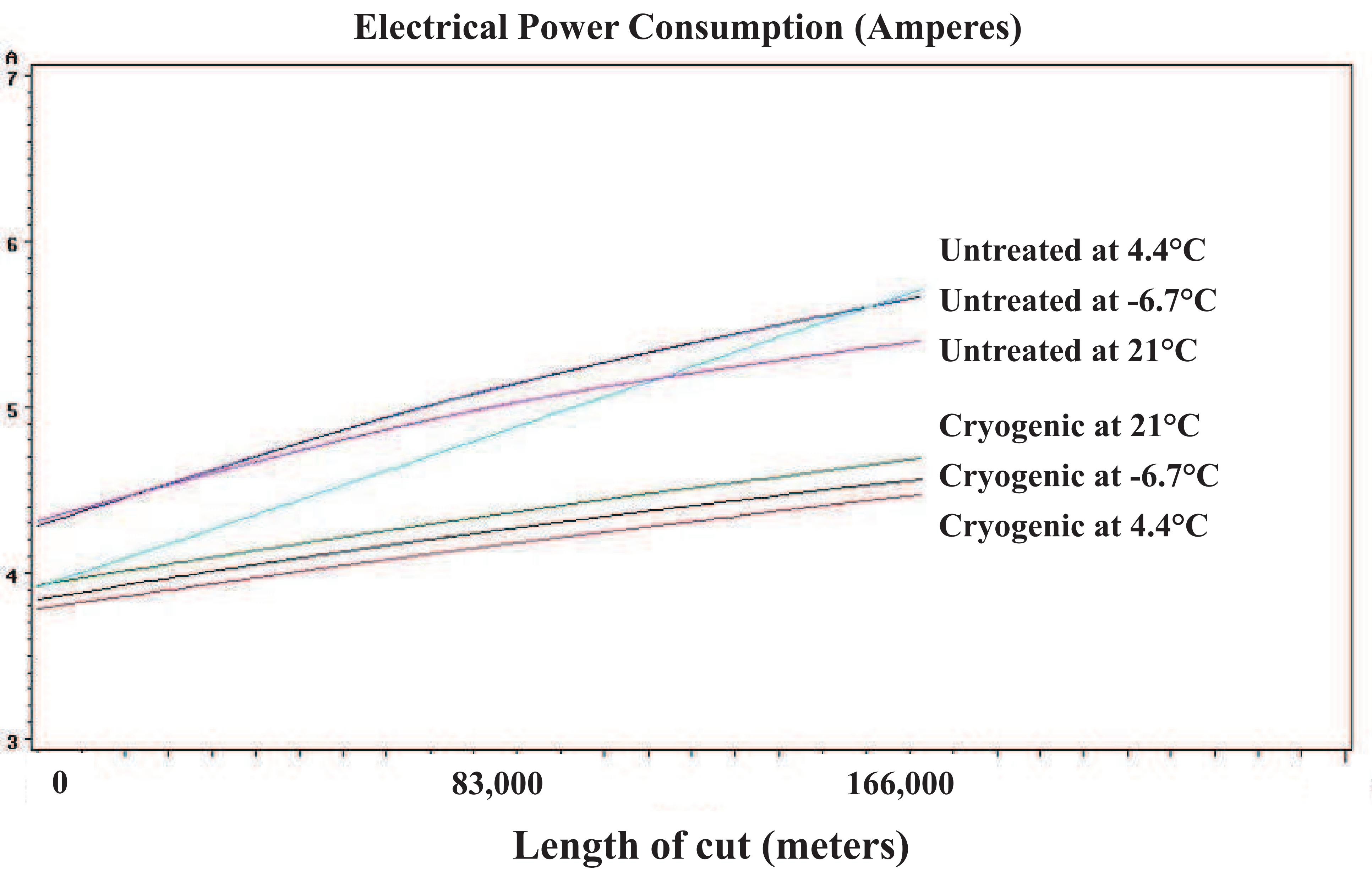


Nitrodation, halogenation, sulfidation, oxidation – high temp phenomena indicators

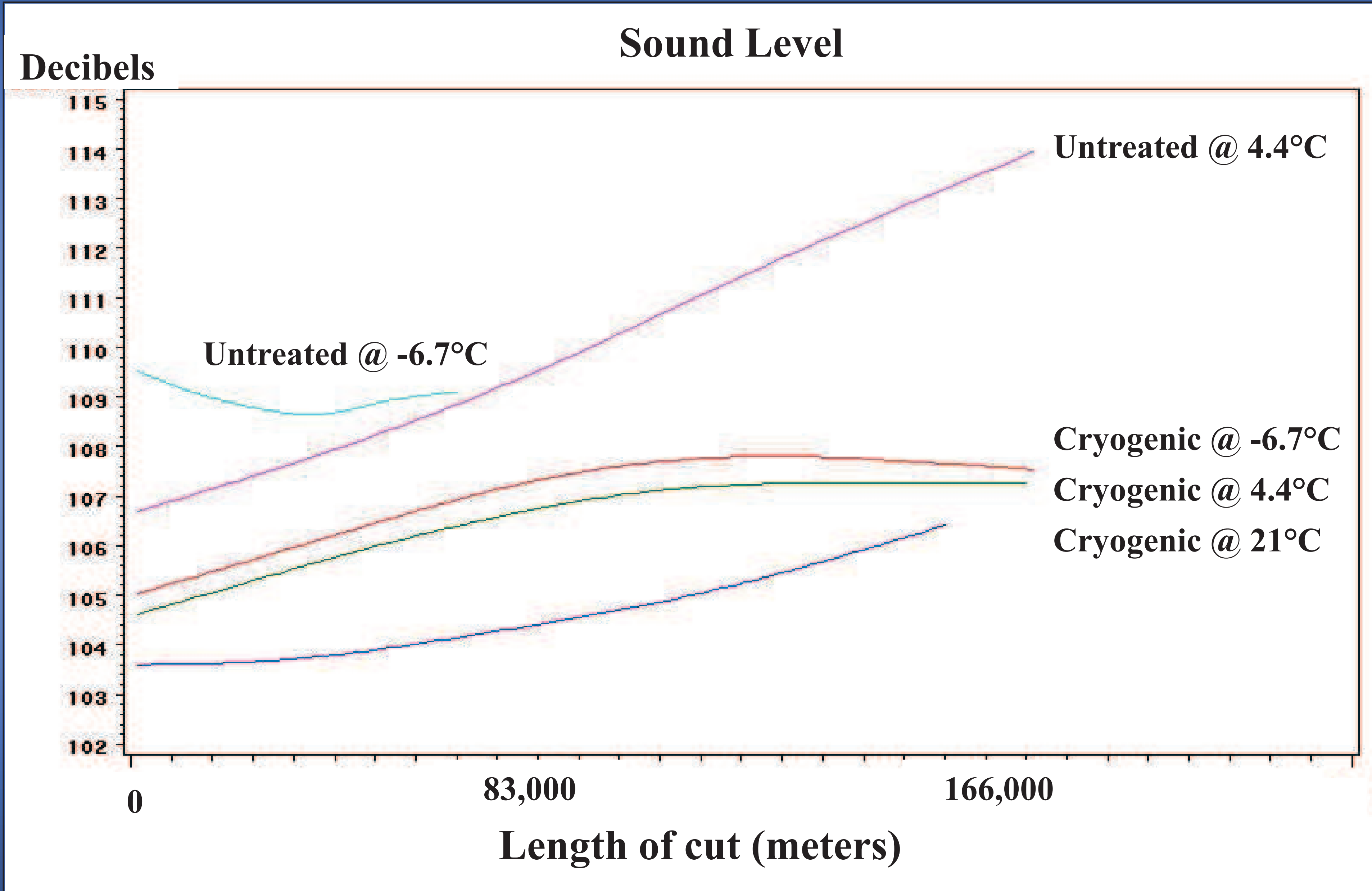
Results and Discussion



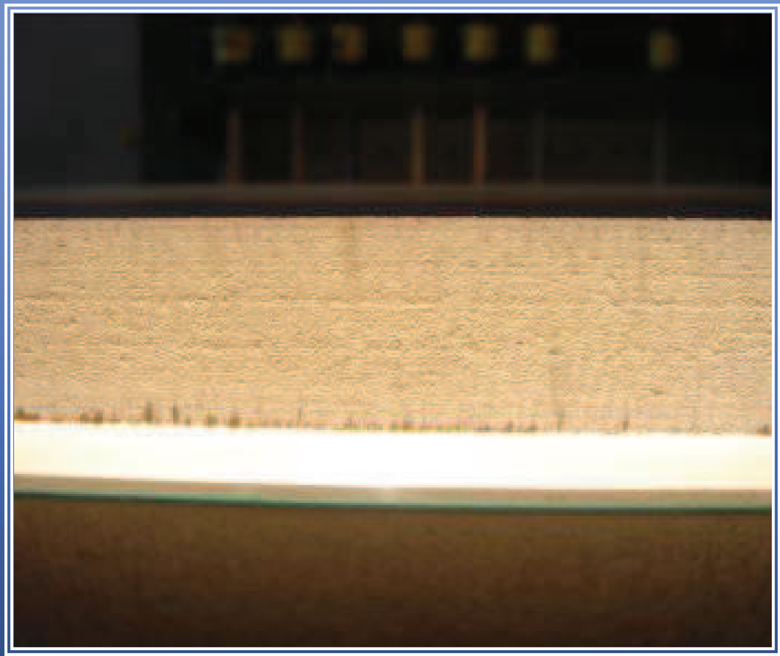
Results and Discussion

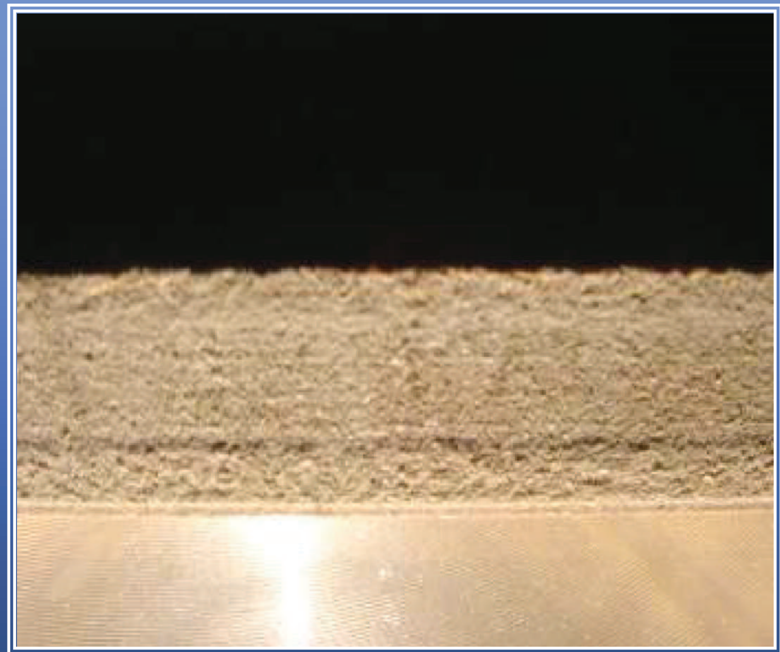


Results and Discussion

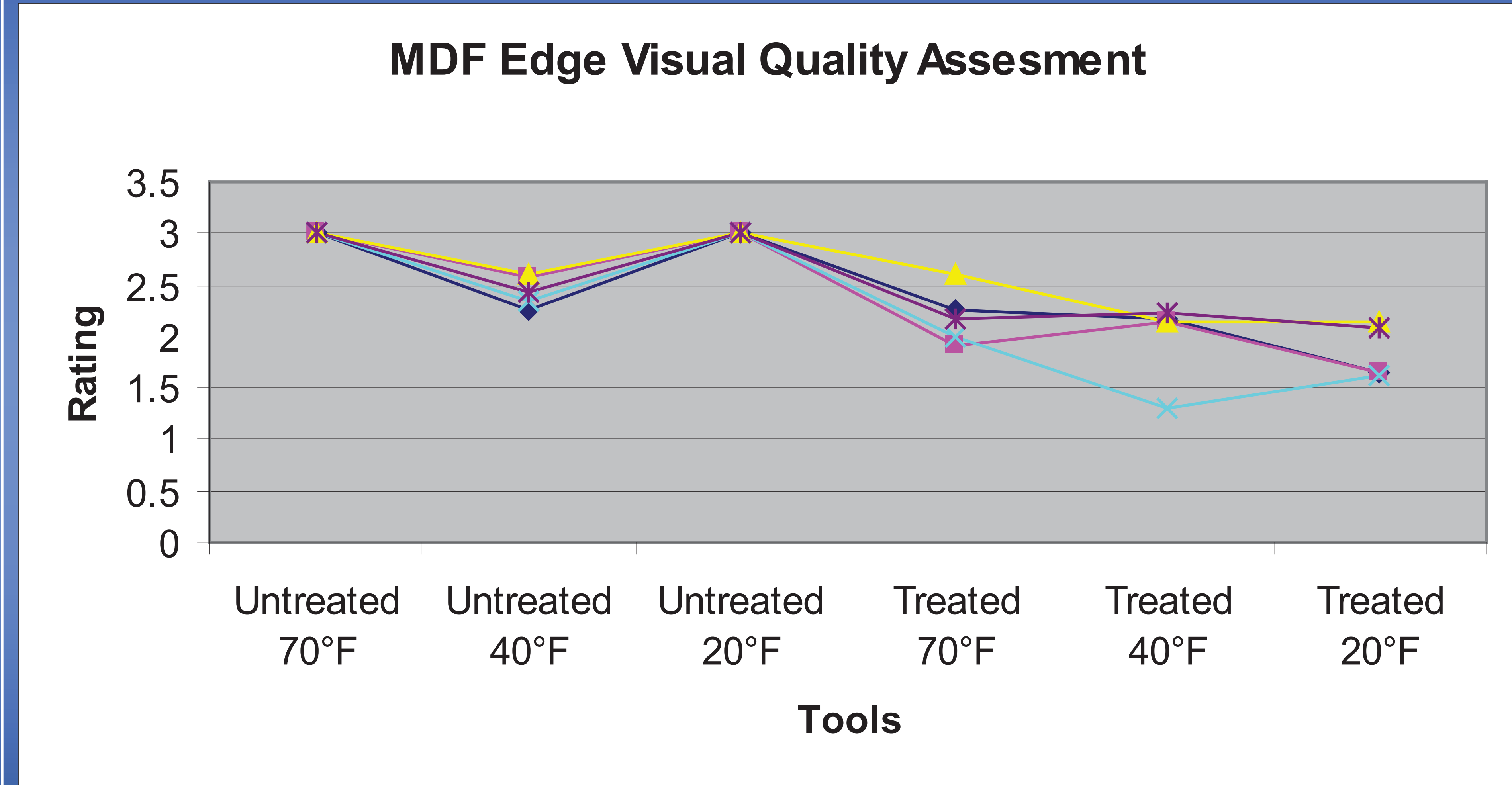


Results and Discussion





Results and Discussion

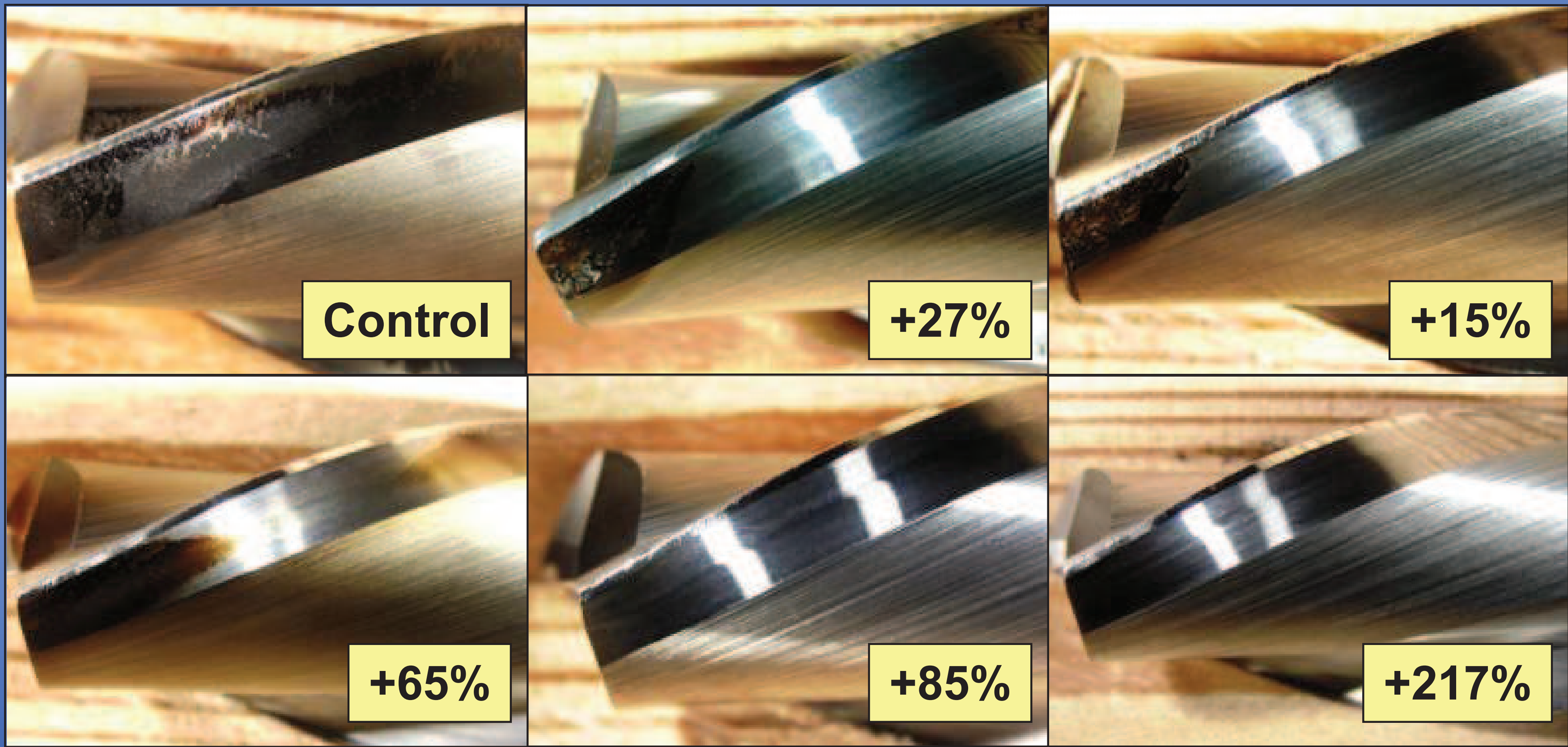


Conclusions

70°F (21°C) | 40°F (4.4°C) | 20°F (-6.7°C)

Untreated

Treated



Estimated increase in tool life

Primary Wood Processing

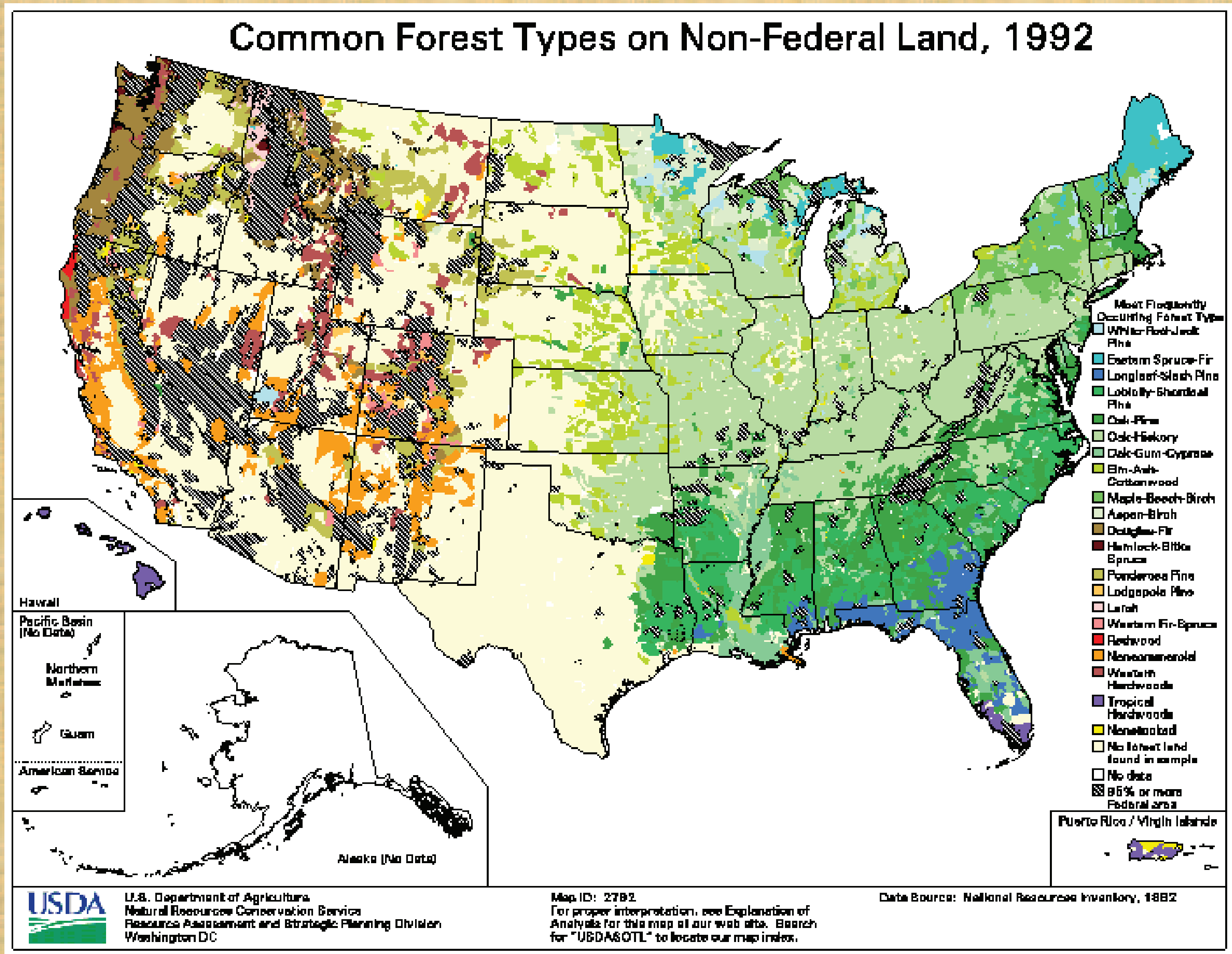
Example: CT Scanning of Logs

Past scanning studies

Numerous past research studies have examined log breakdown value improvements.

Year	Author	# of Logs	Species	% Improvement
1962	Peter	10	Southern Pine	3%
1967	Peter	50	Yellow Poplar	9%
1969	Tsolakides	6	Red Oak	21%
1975	Wagner and Taylor	10	Southern Pine	8%
1980	Richards *et al.*	320	Red Oak	11%
1989	Steele *et al.*	24	Red Oak	12%
1994	Steele *et al.*	6	Red Oak	10%
‘94-‘99	Chang and Guddanti	10	Red Oak	18% -28%

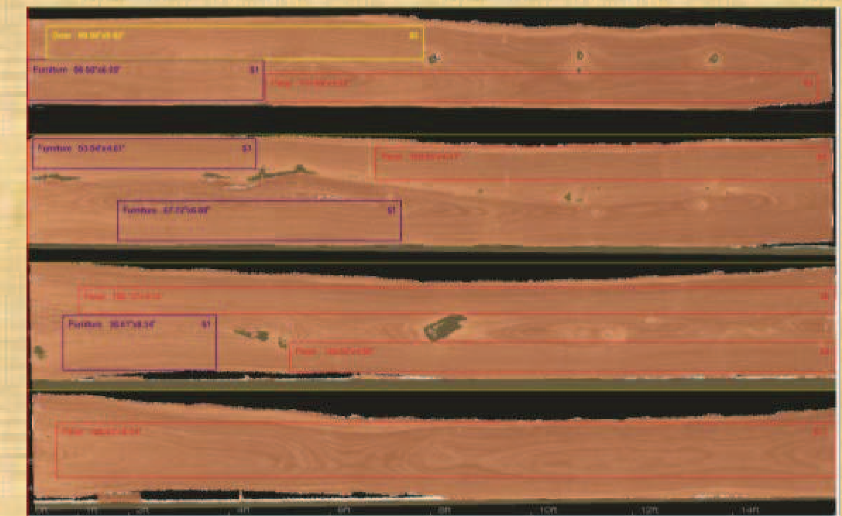
Softwood vs. Hardwood Log Processing



Softwood vs. Hardwood Log Processing

- Softwoods – grading system is based on prediction of strength of lumber.
- Production process is more automated and much faster.

- Hardwoods – grading system is based on appearance characteristics of lumber or sliced veneer.
- Production process relies heavily on experience and skill of operator (headrig, resaw, edger).



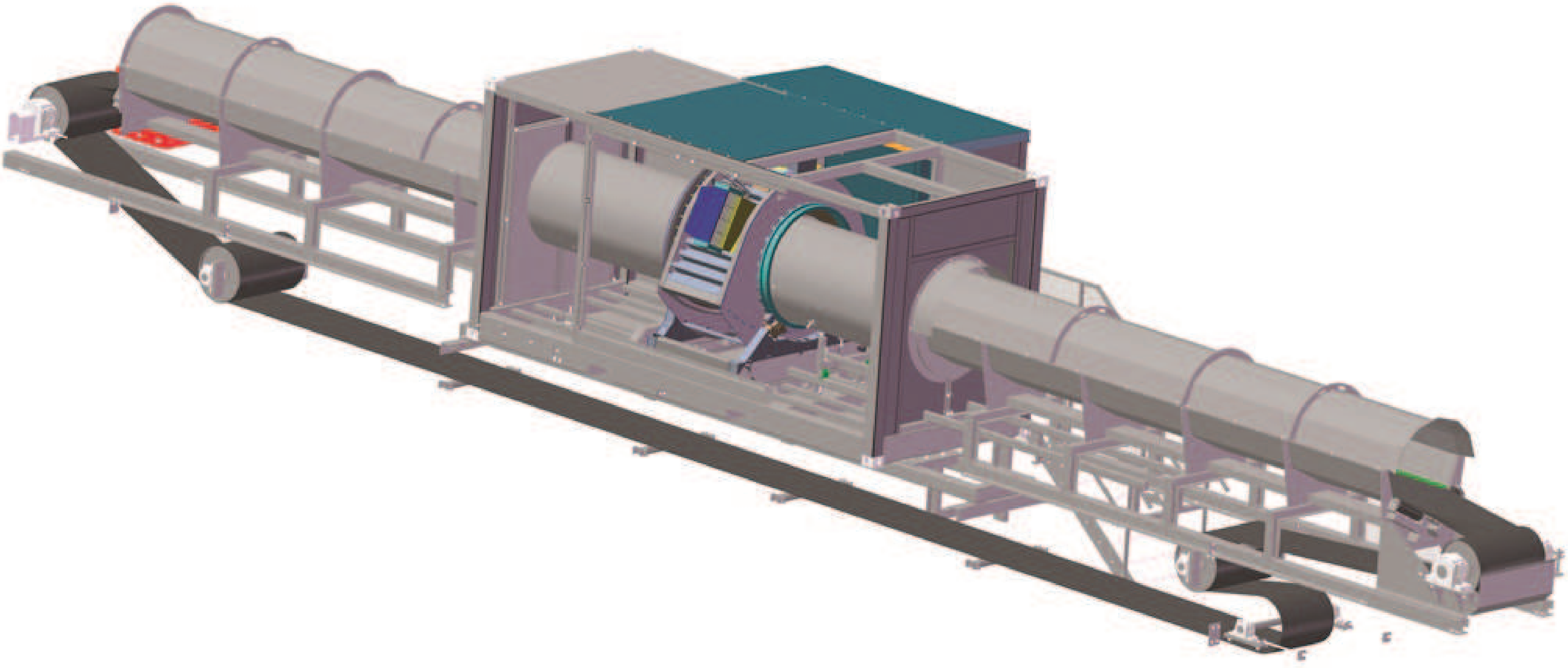
Proof of Concept

Proof of Concept

Results – Sawmill vs. CT Scanner

Gain (%)	Black Cherry	Hard Maple	Red Oak	White Oak	Yellow Poplar	Overall
All Grades	42	33	24	60	87	**46**
Grade 1	20	21	8	83	23	27
Grade 2	45	34	22	42	99	47
Grade 3	194	75	67	46	221	97

CT Scanner Development
Medical vs. Security



MiCROTEC®
INNOVATING WOOD
CT.LOG

CT Scanner Development

• Log Length:	No limit
• Max. Log Diameter:	700 mm
• Gantry aperture:	1200 mm
• Max Log speed:	60 m/min
• X–Y resolution:	approx. 1mm

MiCROTEC® INNOVATING WOOD CT.LOG

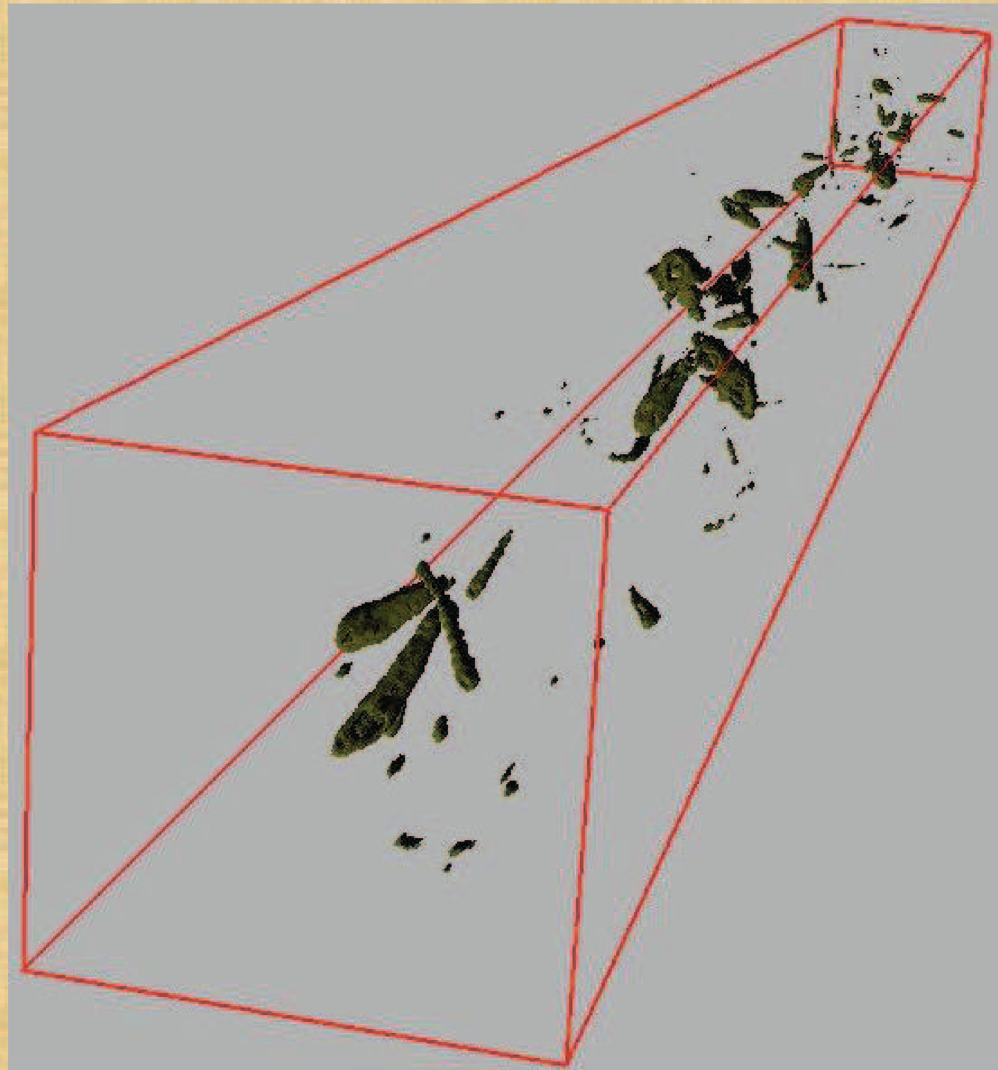

CT.LOG
MiCROTEC

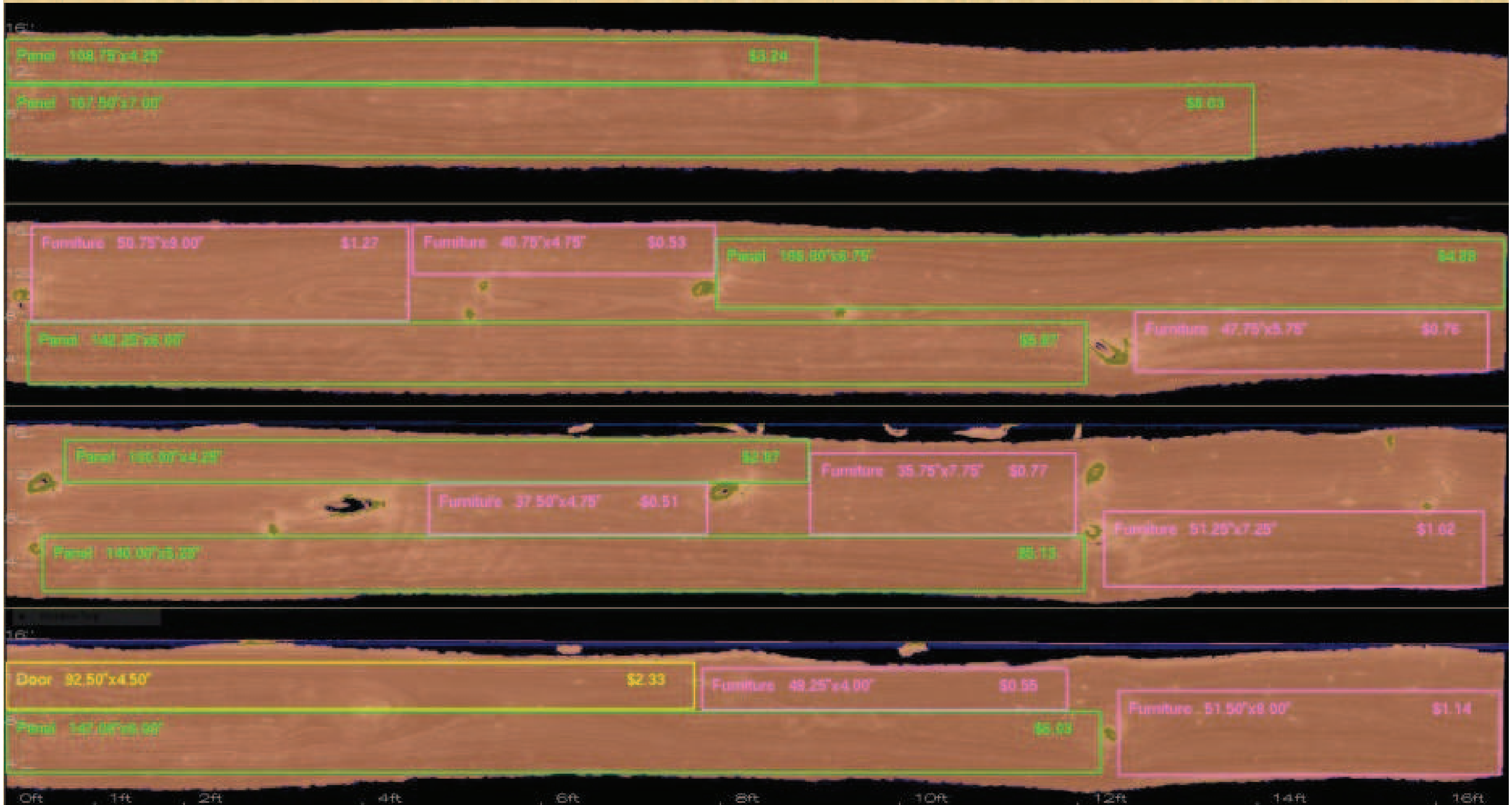
Software Development

- LogView
  - Veneer (full optimization)
  - Sawmill (full optimization)

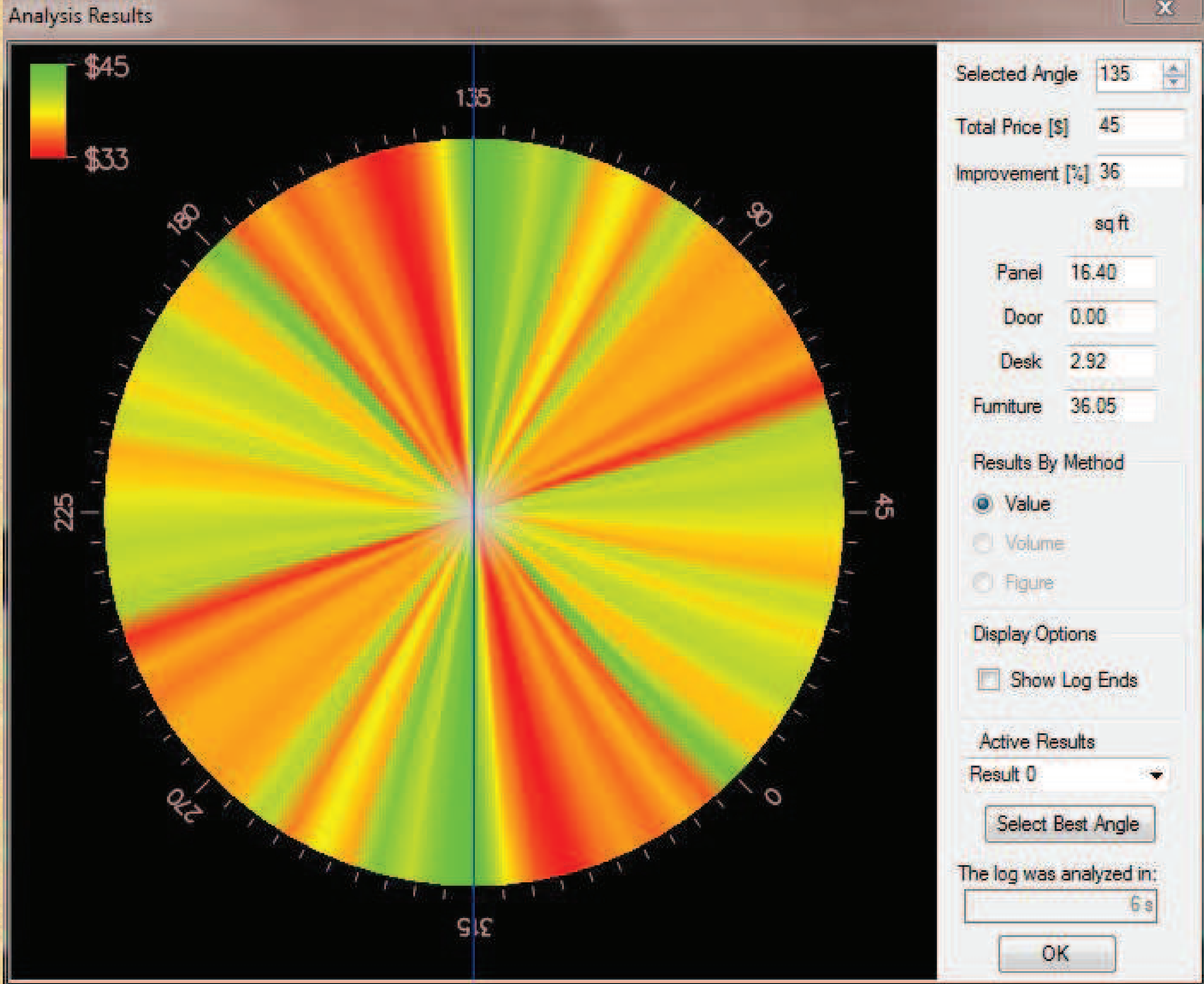
- Developed by Purdue University Hardwood Scanning Center

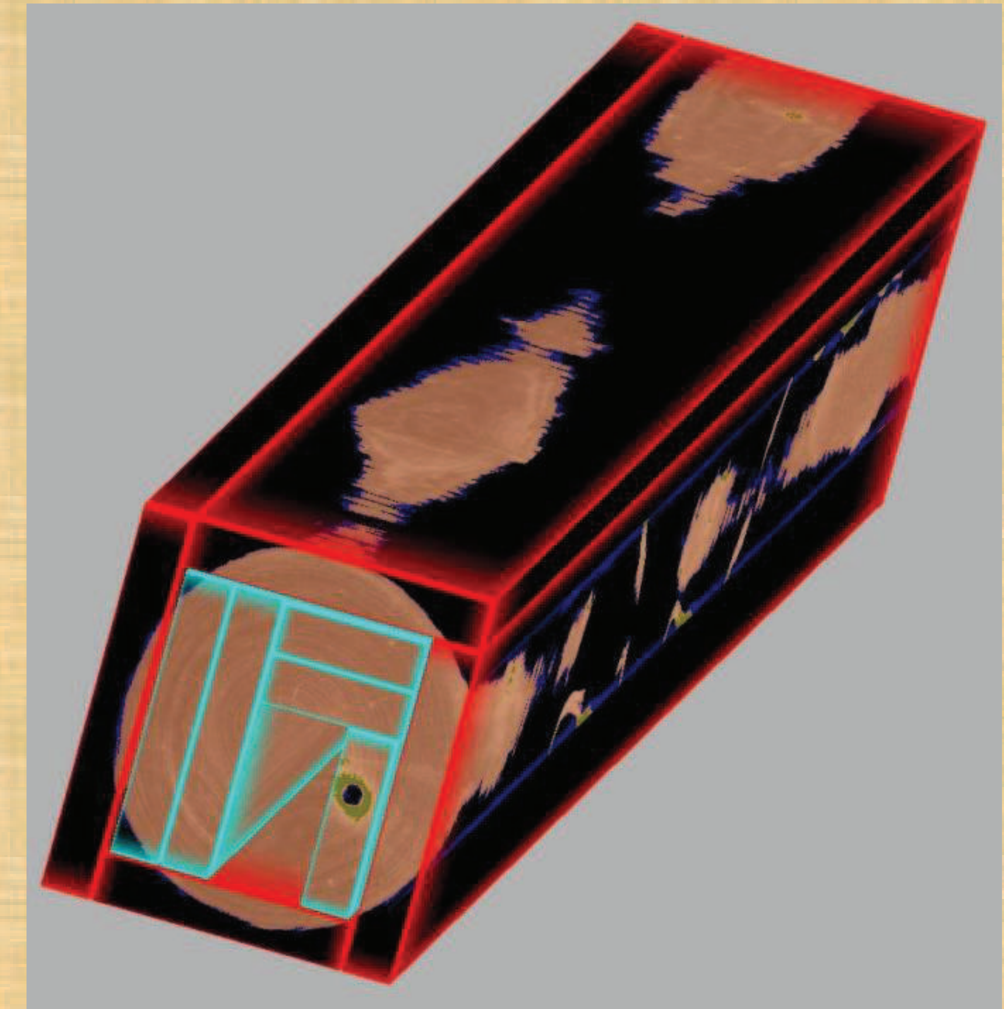
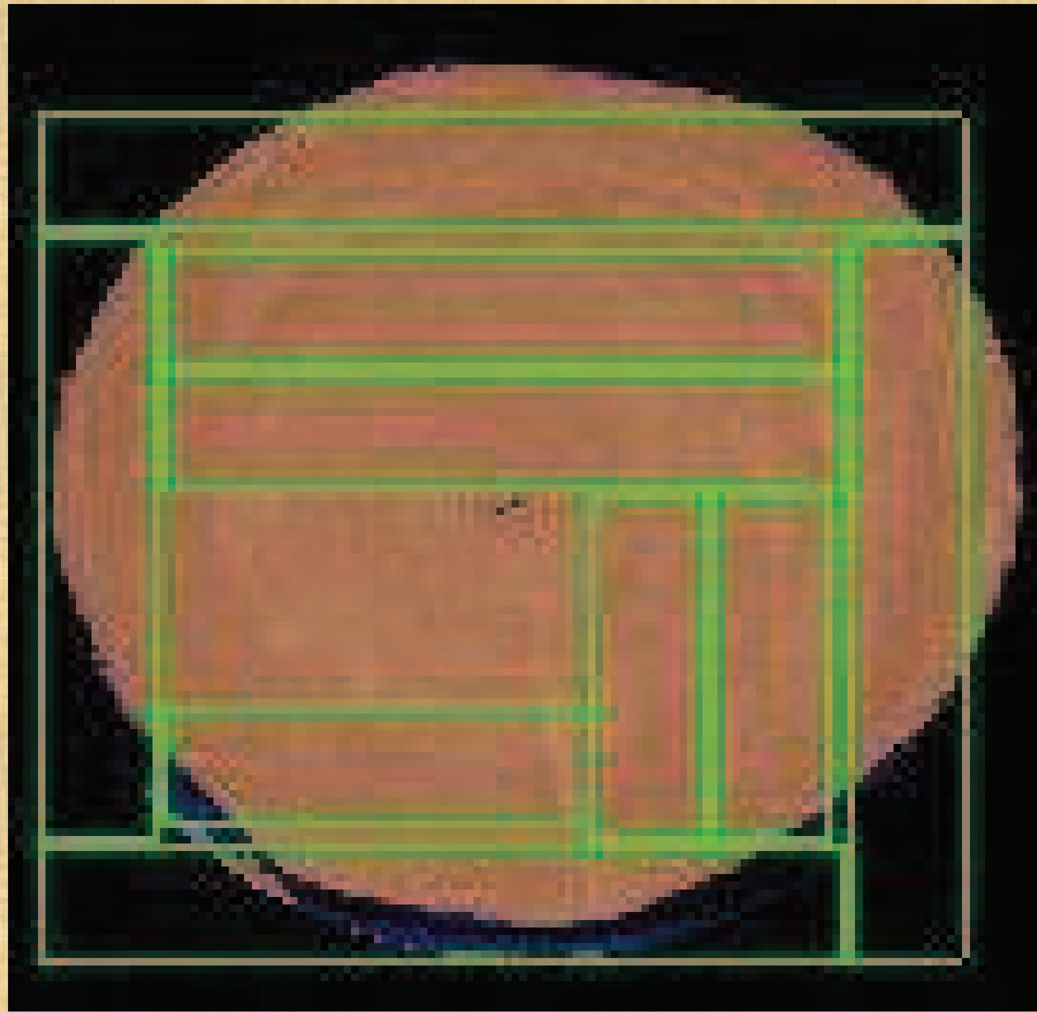
- Commercialized by LogView, LLC





Panel 108.75"x4.25" $3.24
Furniture 50.75"x9.00" $1.27
Furniture 40.75"x4.75" $0.53
Furniture 47.75"x5.75" $0.76
Furniture 35.75"x7.75" $0.77
Furniture 37.50"x4.75" $0.51
Furniture 51.25"x7.25" $1.02
Door 92.50"x4.50" $2.33
Furniture 49.25"x4.00" $0.55
Furniture 51.50"x8.00" $1.14
0ft
1ft
2ft
4ft
6ft
8ft
10ft
12ft
14ft
16ft


Analysis Results
$45
$33
135
180
90
225
45
270
0
315
Selected Angle 135
Total Price [$] 45
Improvement [%] 36
sq ft
Panel 16.40
Door 0.00
Desk 2.92
Furniture 36.05
Results By Method
Value
Volume
Figure
Display Options
Show Log Ends
Active Results
Result 0
Select Best Angle
The log was analyzed in:
6 s
OK


18''
0ft 1ft 2ft 4ft 6ft 8ft 10ft 12ft 14ft 16f

How and Where Can This Technology Be Applied?

- Log merchandising and bucking
- Slicing vs. Peeling
- Hardwood Veneer Slicing – Optimize splitting log into flitches (off-line or in-line)
- Hardwood Sawmills - Optimize log “opening” at headrig to maximize yield of premium product (in-line between debarker and headrig)

CT Log Scanning

Summary

- **CT Technology exists today to see *inside* a log**
- **CT Technology can be applied at various points in the process to satisfy multiple applications**