

# **Innovations in Wood Processing**

**Rado Gazo**

# 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

Control

+27%

+15%

Treated

+65%

+85%

+217%

Estimated increase in tool life

# **Primary Wood Processing**

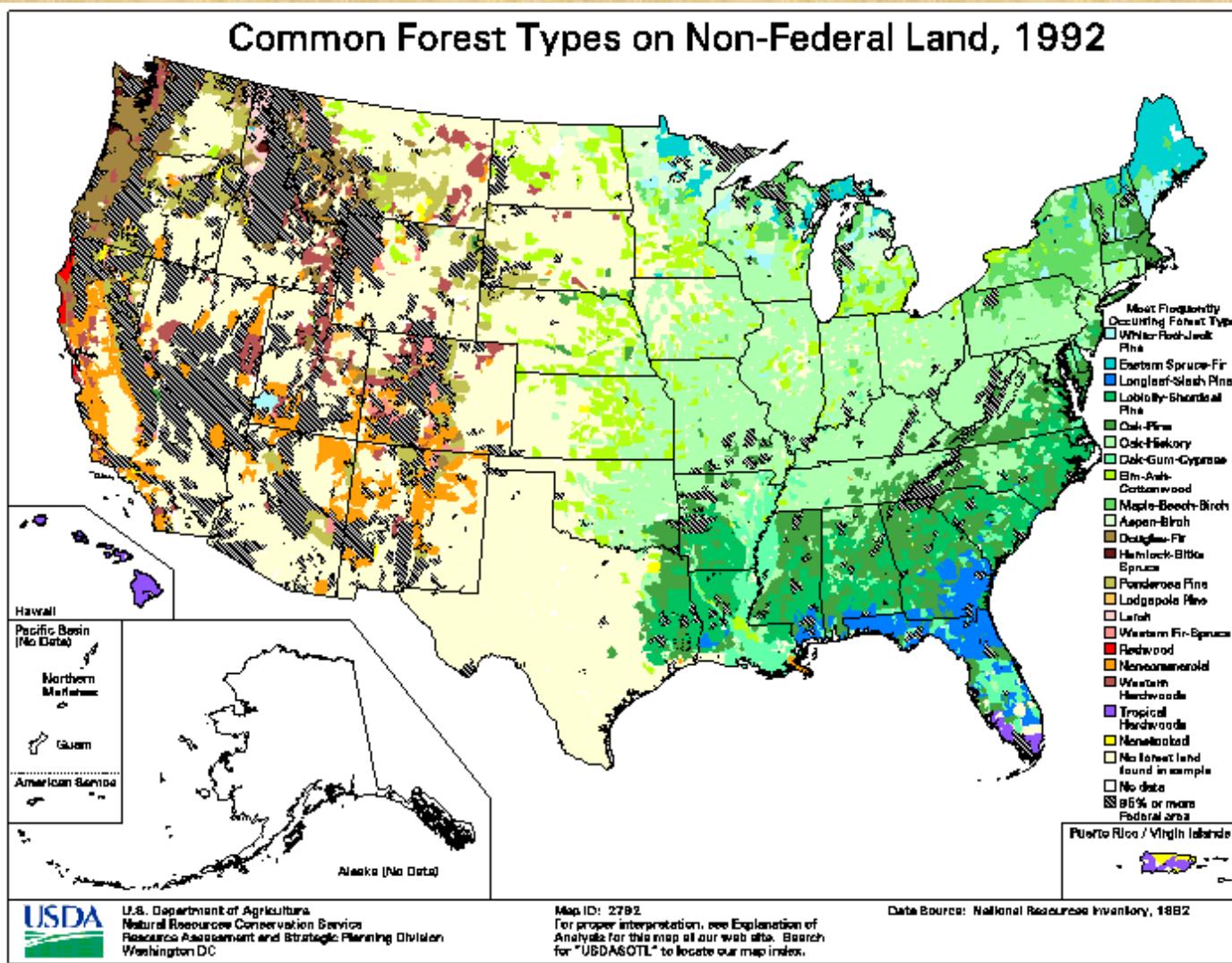
**Example: CT Scanning of Logs**

# Past scanning studies

Numerous past research studies have examined log breakdown value improvements.

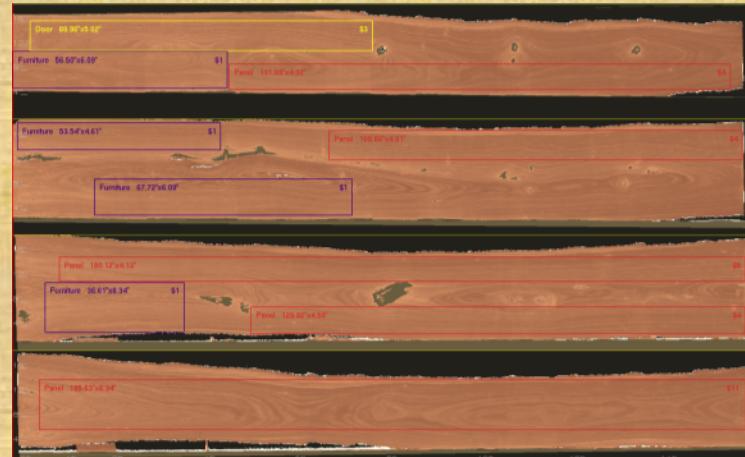
Year	Author	# of Logs	Species	% Improvement
1962	Peter	10	Southern Pine	3%
1967	Peter	50	Yellow Poplar	9%
1969	Tsolakides	6	Red Oak	21%
1975	Wagner and Taylor	10	Southern Pine	8%
1980	Richards <i>et al.</i>	320	Red Oak	11%
1989	Steele <i>et al.</i>	24	Red Oak	12%
1994	Steele <i>et al.</i>	6	Red Oak	10%
'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	<b>46</b>

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All Grades	42	33	24	60	87	<b>46</b>
Grade 1	20	21	8	83	23	27

# Results – Sawmill vs. CT Scanner

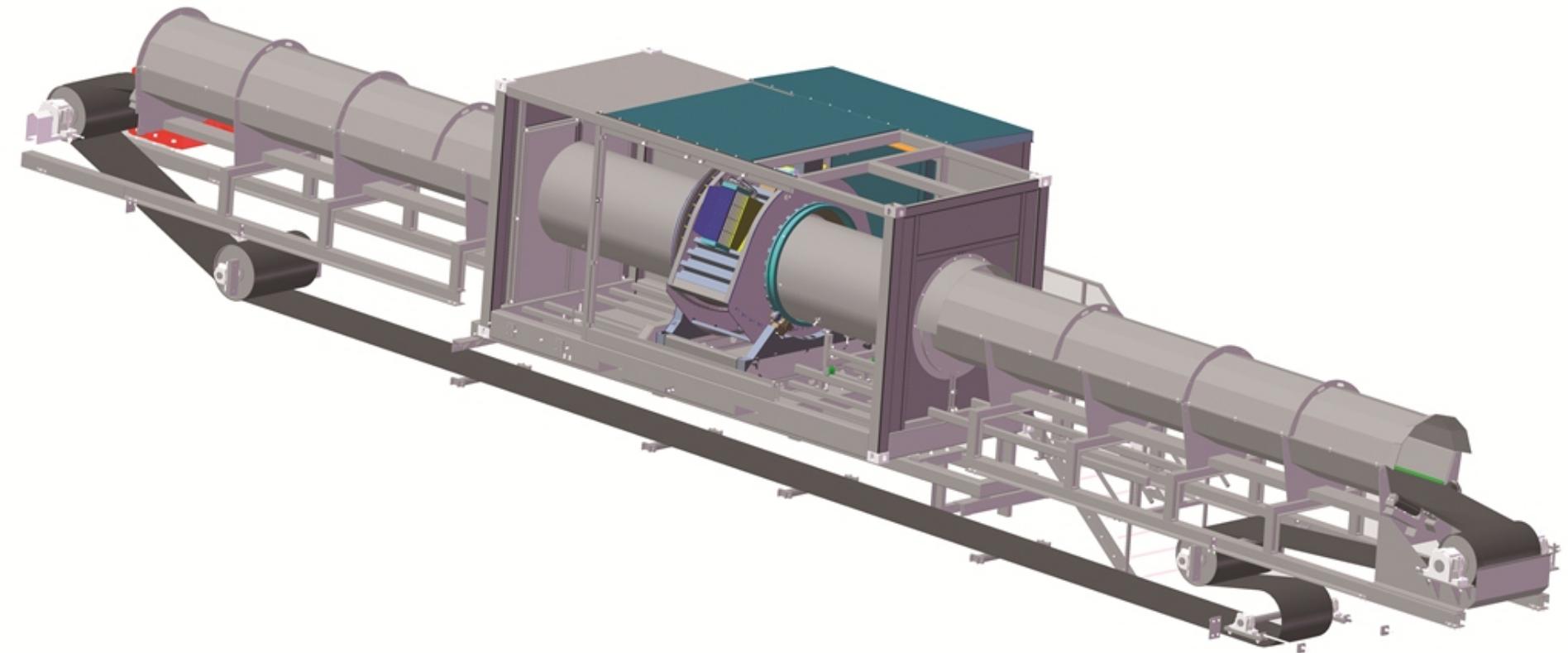
Gain (%)	Black Cherry	Hard Maple	Red Oak	White Oak	Yellow Poplar	Overall
All Grades	42	33	24	60	87	<b>46</b>
Grade 1	20	21	8	83	23	27
Grade 2	45	34	22	42	99	47

# Results – Sawmill vs. CT Scanner

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



# 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



CT. LOG

MICROTEC

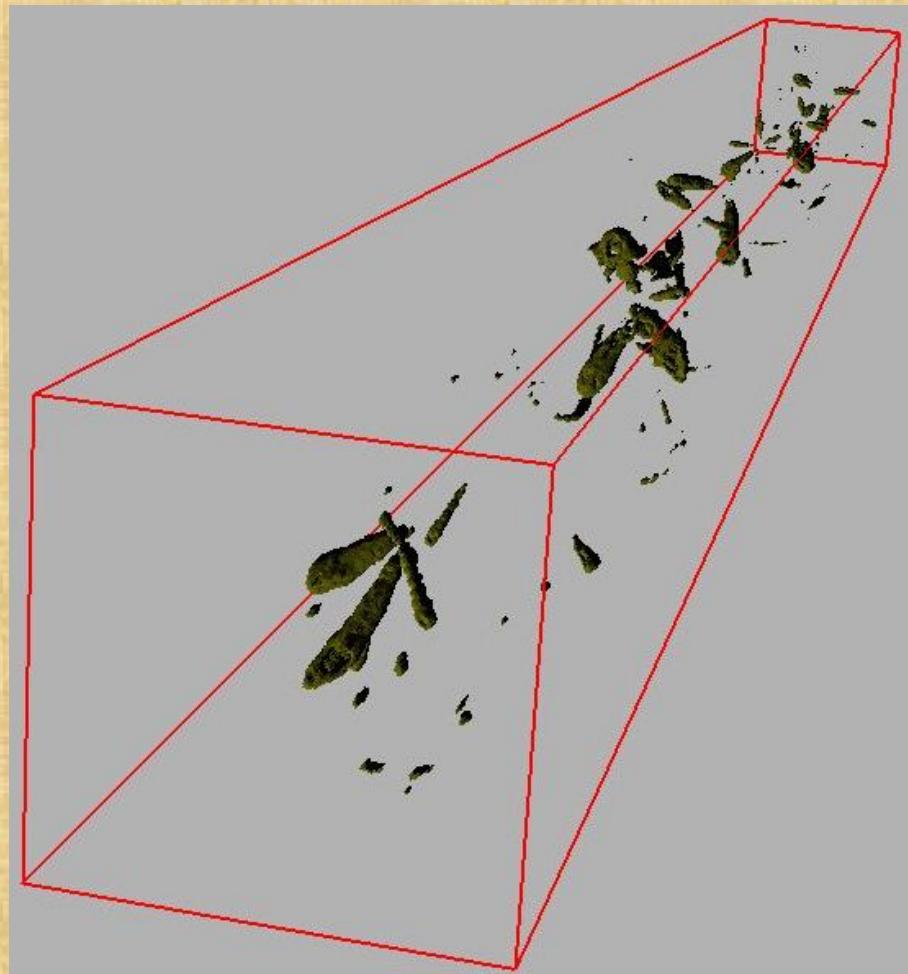
# Software Development

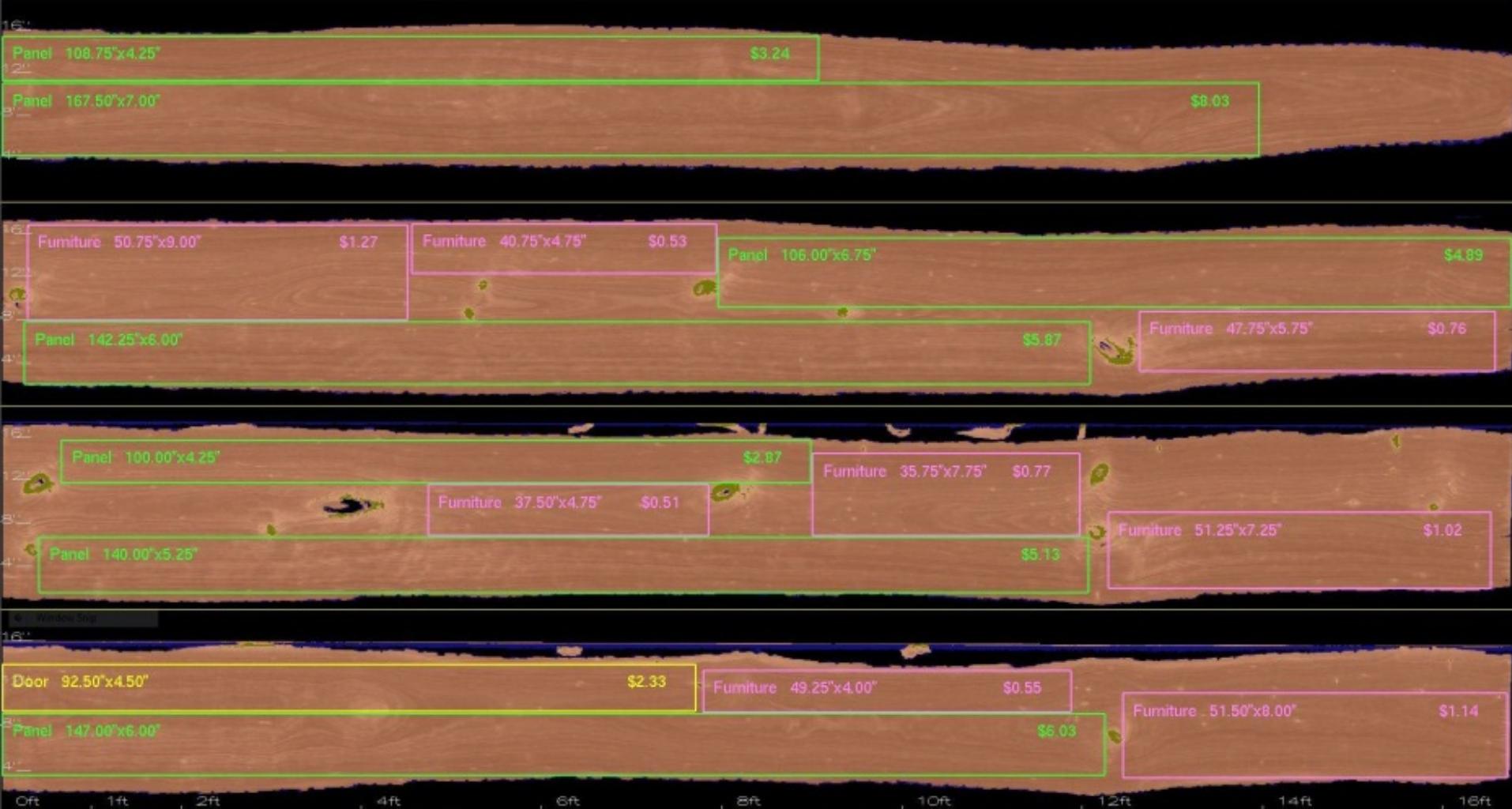
- LogView
  - Veneer (full optimization)
  - Sawmill (full optimization)
- Developed by Purdue University Hardwood Scanning Center
- Commercialized by LogView, LLC

# Industry Adoption

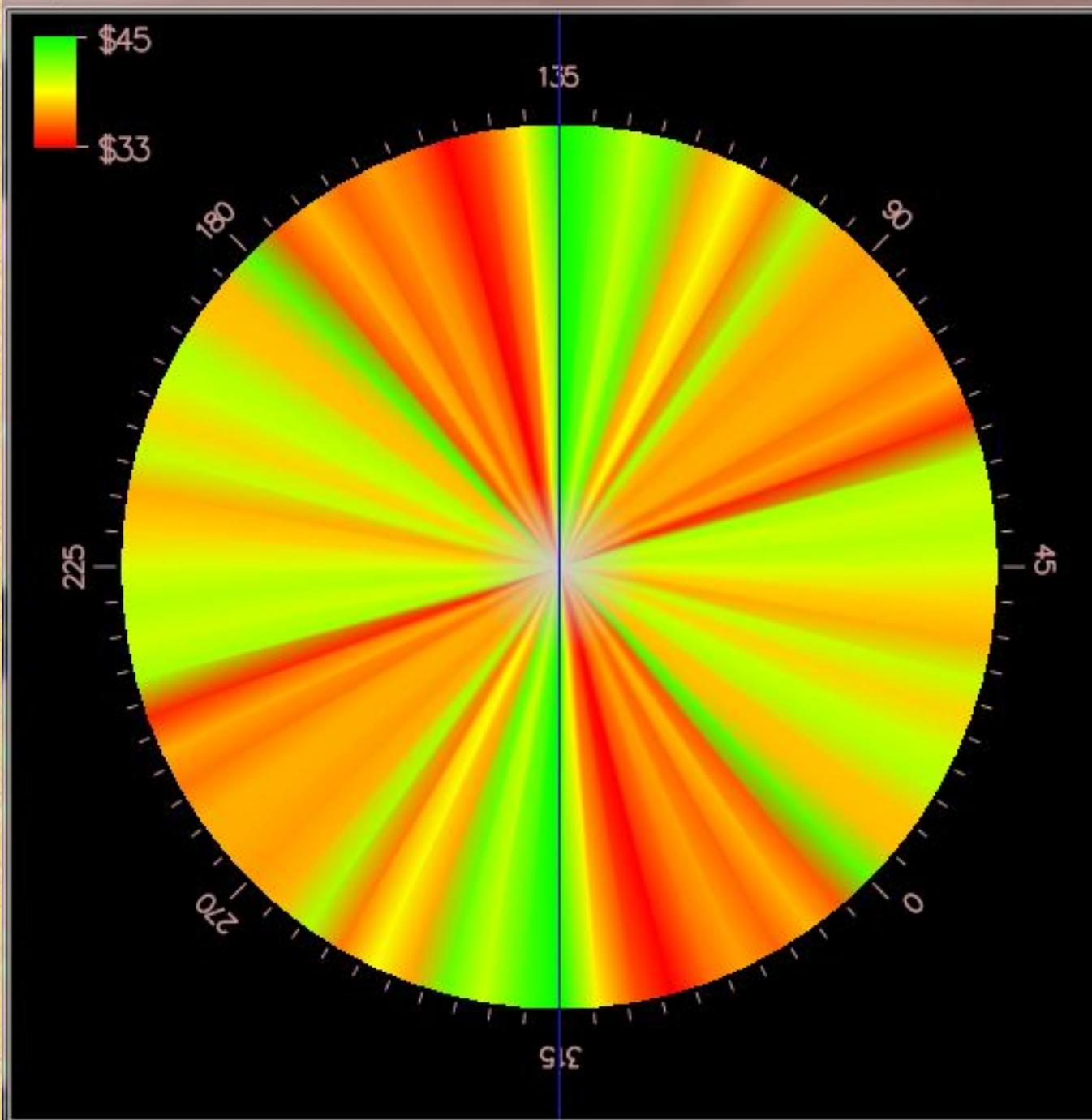
- Public test demonstration in selected mills
  - Veneer
  - Sawmill







## Analysis Results



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

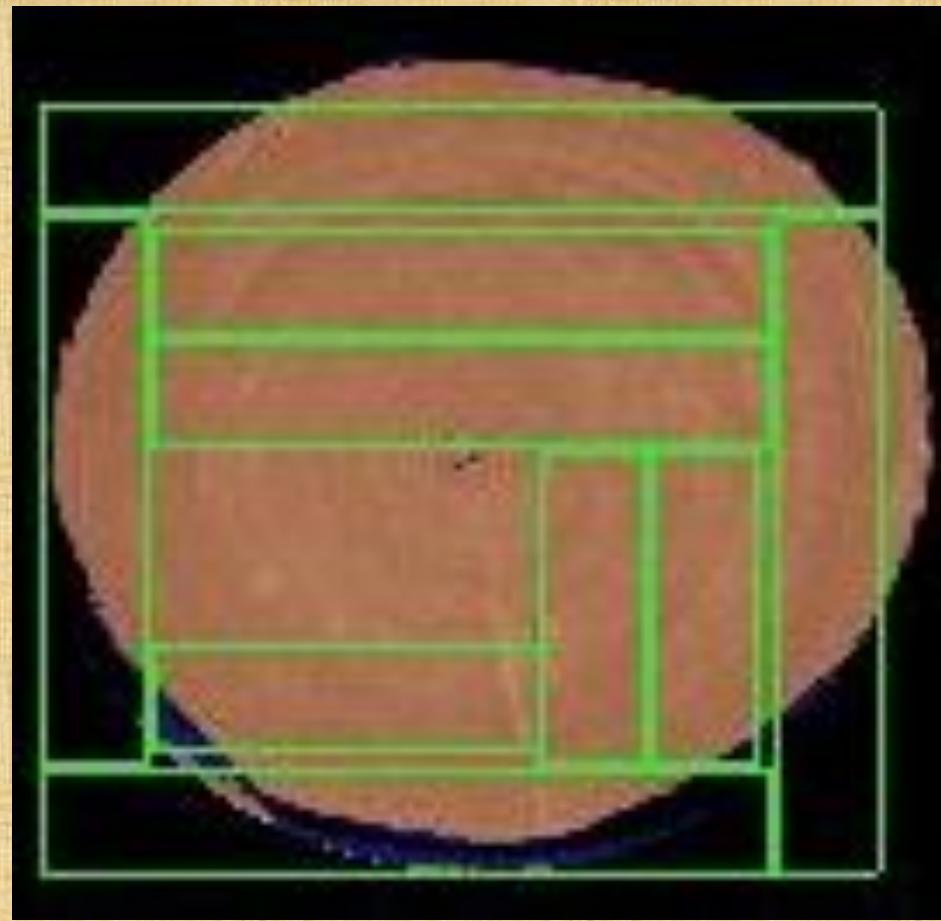
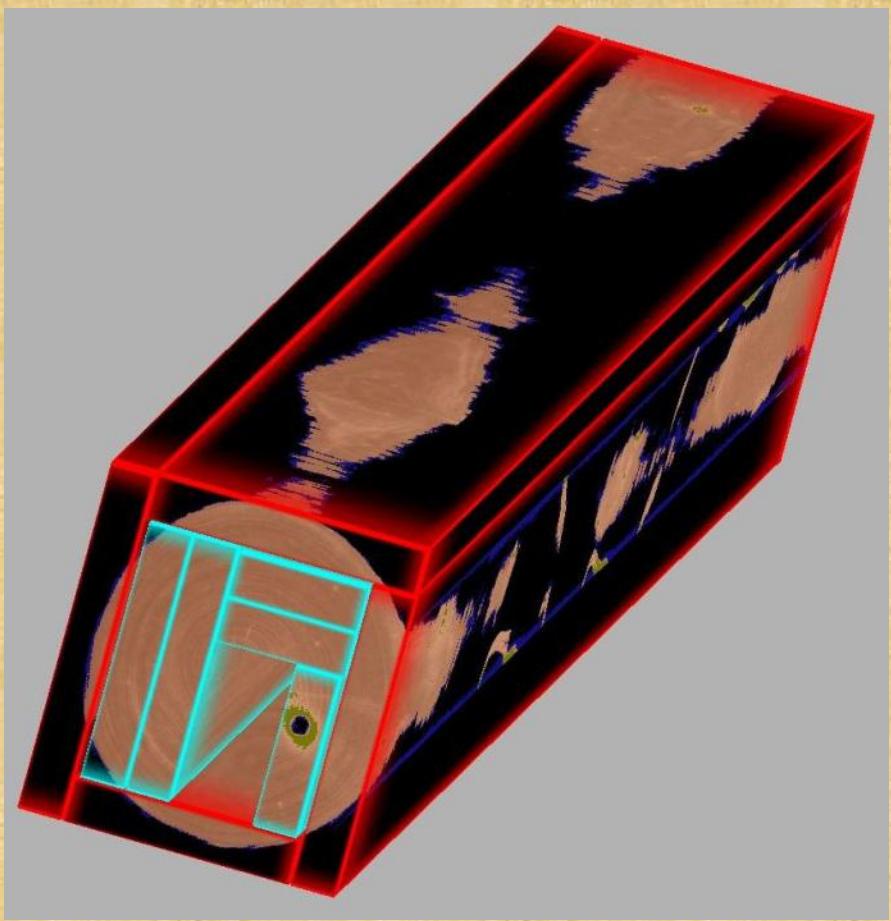
Result 0

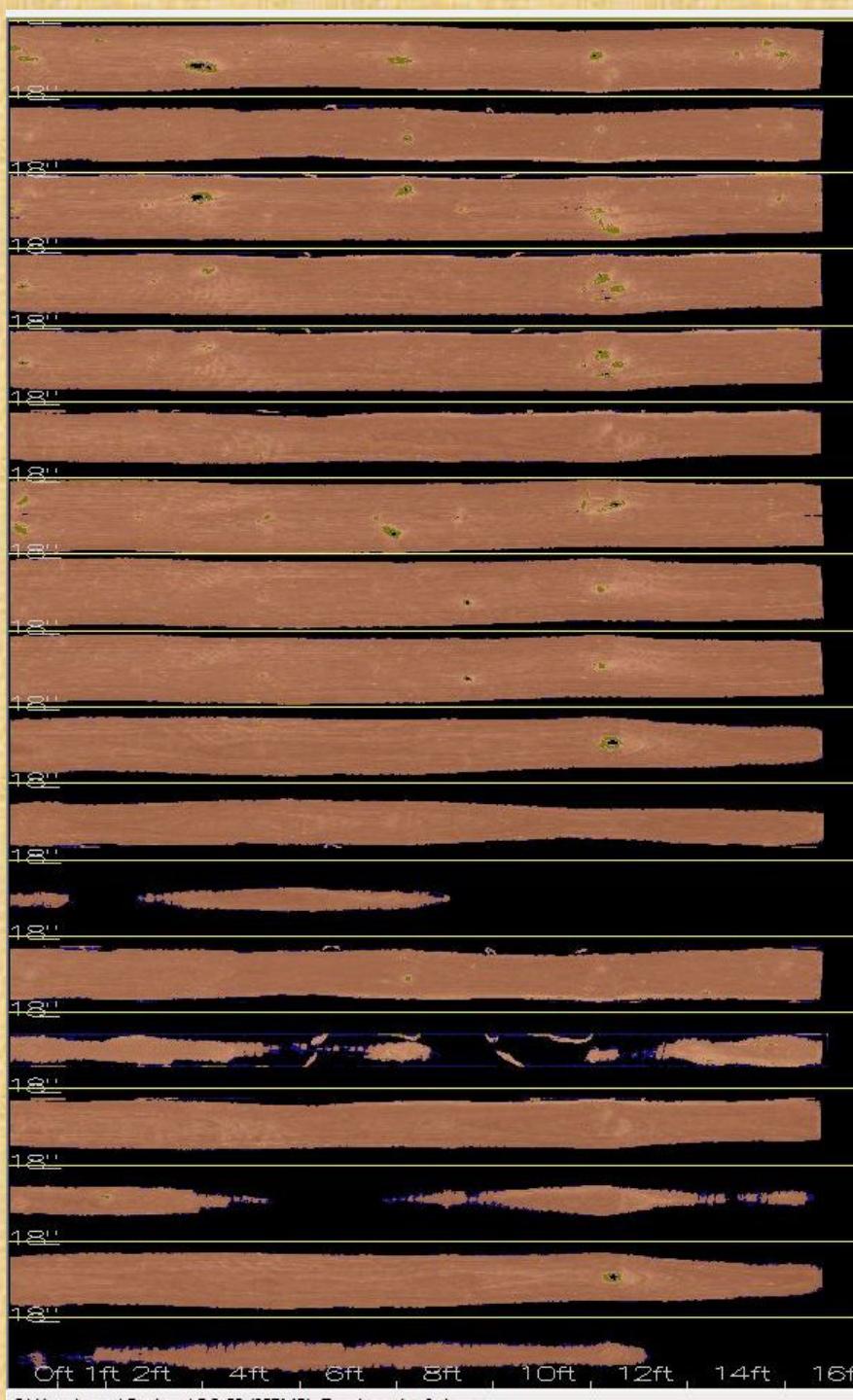
Select Best Angle

The log was analyzed in:

6 s

OK





# 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

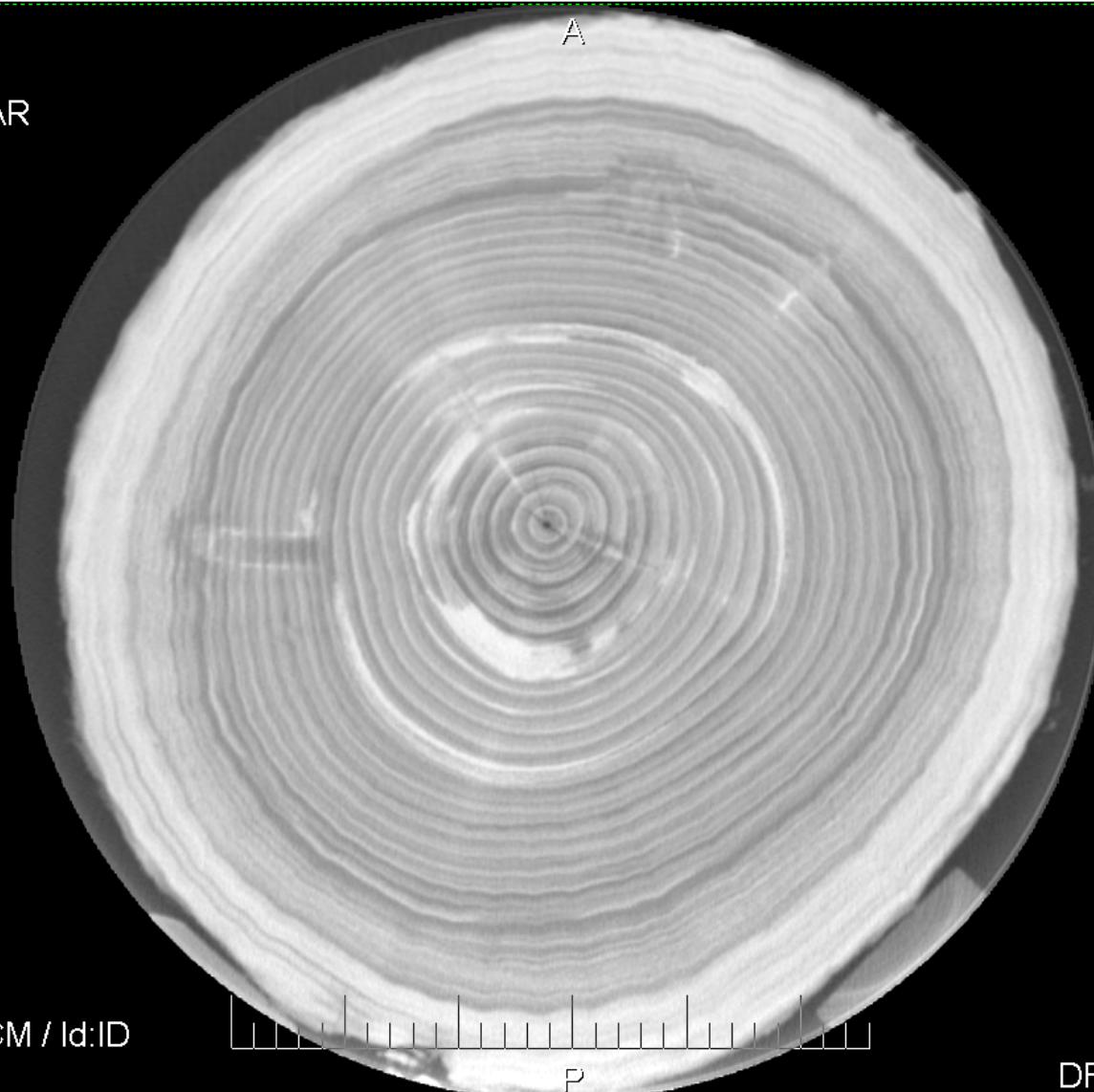
- CT Technology exists today to see *inside* a log
- CT Technology can be applied at various points in the process to satisfy multiple applications

# **The Species**

HiSpeed CT/i  
Ex: 25  
YELLOW-POPLAR  
Se: 4/4  
Im: 33/60  
Ax: 1160.0  
  
Mag: 1.6x

R

140.0 kV  
200.0 mA  
5.0 mm/1.0:1  
Tilt: 0.0  
1.0 s  
Lin:DCM / Lin:DCM / Id:ID  
W:1500 L:-600



HiSpeed CTi  
CHERRY COOKIE  
O 05-02-07CC  
Acc:  
2007 May 02  
Acq Tm: 11:27:20

512 x 512  
STANDARD

L

DFOV: 47.9 x 47.9cm

**Yellow Popular**

HiSpeed CT/i

Ex: 8714

Se: 7/2

Im: 1/330

Ax: S0.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

HARD MAPLE 13" 10'

O HM-67-1

Acc:

2007 May 23

Acq Tm: 14:17:02

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Hard Maple**

HiSpeed CT/i

Ex: 20514

Se: 1/1

Im: 231/320

Ax: 1250.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Black Cherry 16" 16'

O BC-40-2

Acc:

2007 Jun 08

Acq Tm: 09:04:22

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Black Cherry**

HiSpeed CT/i

Ex: 20532

Se: 2/2

Im: 679/735

Ax: 190.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Red Oak 16" 12'

O RO-25-1

Acc:

2007 Jun 15

Acq Tm: 13:32:25

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

**Red Oak**

HiSpeed CT/i

Ex: 20529

Se: 1/1

Im: 372/565

Ax: 155.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

White Oak 14" 16'

O WO-81-3

Acc:

2007 Jun 14

Acq Tm: 14:47:19

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

**White Oak**

**What can we see in  
wood?**

**We can see...**

**Knots & Voids**

HiSpeed CT/i

Ex: 20510

Se: 1/1

Im: 134/300

Ax: 165.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1502 L:-600

A

Purdue University at Pike Lumber

Black Cherry 17" 14'

O BC-56-3

Acc:

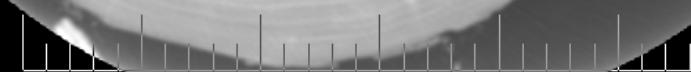
2007 Jun 07

Acq Tm: 08:47:46

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Sound Knot in Black Cherry**

HiSpeed CT/i

Ex: 20534

Se: 1/1

Im: 171/185

Ax: 1250.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-599

A

Purdue University at Pike Lumber

Walnut with Metal

O Walnut

Acc:

2007 Jun 15

Acq Tm: 17:21:58

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Carpenter Ants in Black Walnut**

HiSpeed CT/i

Ex: 20521

Se: 2/2

Im: 632/745

Ax: 1155.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

White Oak 16" 12'

O WO-84-1

Acc:

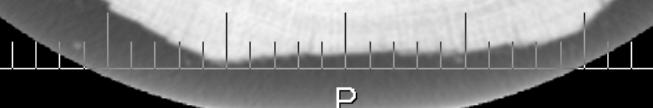
2007 Jun 12

Acq Tm: 11:03:28

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Checking In White Oak**

HiSpeed CT/i

Ex: 8721

Se: 2/2

Im: 580/805

Ax: 1195.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Hard Maple 16" 16'

O HM-60-2

Acc:

2007 May 25

Acq Tm: 10:53:02

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Un-Sound Knot in Hard Maple**

HiSpeed CT/i

Ex: 8713

Se: 2/1

Im: 44/660

Ax: I215.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

HARD MAPLE 15" 10'

O HM-68-4

Acc:

2007 May 23

Acq Tm: 09:11:13

512 x 512

STANDARD

L

Area: 0.1 sq.cm  
Mean: 185.5 HU  
Std.Dev.: 138.1 HU

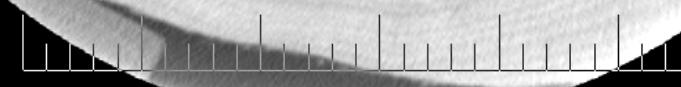
[0.8 cm]  
++

[0.8 cm]  
++

Area: 0.2 sq.cm  
Mean: 116.3 HU  
Std.Dev.: 102.1 HU

[1.0 cm]  
++

[1.1 cm]  
++



P

DFOV: 47.9 x 47.9cm

**Pin Knots in Hard Maple**

**We can see...**

# **Sapwood vs. Heartwood**

HiSpeed CT/i  
Ex: 25  
YELLOW-POPLAR  
Se: 4/4  
Im: 33/60  
Ax: 1160.0  
  
Mag: 1.6x

R

140.0 kV  
200.0 mA  
5.0 mm/1.0:1  
Tilt: 0.0  
1.0 s  
Lin:DCM / Lin:DCM / Id:ID  
W:1500 L:-600

A



HiSpeed CTi  
CHERRY COOKIE  
O 05-02-07CC  
Acc:  
2007 May 02  
Acq Tm: 11:27:20  
  
512 x 512  
STANDARD

L

DFOV: 47.9 x 47.9cm

**Sap vs. Heart in Yellow Popular**

HiSpeed CT/i

Ex: 1007

Helical Scan

Se: 5/1

Im: 216/660

Ax: 1175.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s/He

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

HiSpeed CTi

HARD MAPLE 14" 10'

O HM-65-1

Acc:

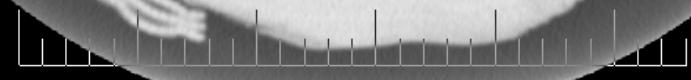
2007 May 17

Acq Tm: 12:26:03

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Sap vs. Heart in Hard Maple**

HiSpeed CT/i

Ex: 20496

Se: 2/2

Im: 458/1000

Ax: I185.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Black Cherry 16" 16'

O BC-41-4

Acc:

2007 Jun 01

Acq Tm: 15:04:38

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Sap vs. Heart in Black Cherry**

HiSpeed CT/i

Ex: 8723

Se: 2/2

Im: 54/315

Ax: 1265.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Hard Maple 17" 16'

O HM-70-2

Acc:

2007 May 29

Acq Tm: 09:13:38

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Stain in Hard Maple**

HiSpeed CT/i

Ex: 8723

Se: 2/2

Im: 302/315

Ax: 15.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Hard Maple 17" 16'

O HM-70-2

Acc:

2007 May 29

Acq Tm: 10:08:43

512 x 512

STANDARD

L

P

**Stain in Hard Maple**

DFOV: 47.9 x 47.9cm

HiSpeed CT/i  
Ex: 1006  
Helical Scan  
Se: 2/1  
Im: 621/633  
Ax: I100.0  
  
Mag: 1.6x

R

120.0 kV  
250.0 mA  
5.0 mm/1.0:1  
Tilt: 0.0  
1.0 s/He  
Lin:DCM / Lin:DCM / Id:ID  
W:1500 L:-600

A

**Stain in Hard Maple**

HiSpeed CTi  
HARD MAPLE 14" 10'  
O HM-69-1  
Acc:  
2007 May 17  
Acq Tm: 11:09:04

512 x 512  
STANDARD

L

P

DFOV: 47.9 x 47.9cm

HiSpeed CT/i

Ex: 24

HEAD

Se: 1/9

Im: 25/40

Ax: 1120.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

HiSpeed CTi

OAK 1A

O 05-01-07-2

Acc:

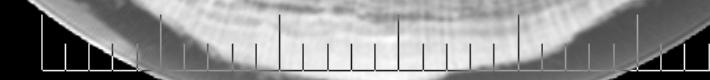
2007 May 01

Acq Tm: 15:48:08

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Stain in Red Oak**

**We can see...**

# **Lumber Defects**

HiSpeed CT/i

Ex: 20498

Se: 4/4

Im: 15/300

Ax: I70.0

Mag: 1.6x

R

120.0 kV

100.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-597

A

Purdue University at Pike Lumber

LUMBER

O LBR-1

Acc:

2007 Jun 01

Acq Tm: 17:39:09

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

**Pin Knot in Black Walnut Lumber**

HiSpeed CT/i

Ex: 20498

Se: 4/4

Im: 46/300

Ax: 1225.0

Mag: 1.6x

R

120.0 kV

100.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-597

A

Purdue University at Pike Lumber

LUMBER

O LBR-1

Acc:

2007 Jun 01

Acq Tm: 17:39:09

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

**Powder Post Beetle in Red Oak Lumber**

HiSpeed CT/i

Ex: 20498

Se: 4/4

Im: 65/300

Ax: 120.0

Mag: 1.6x

R

120.0 kV

100.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

LUMBER

O LBR-1

Acc:

2007 Jun 01

Acq Tm: 17:41:01

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

**Honeycomb in Red Oak & Black Walnut Lumber**

**We can see...**

# **The Unpredictable**

HiSpeed CT/i

Ex: 20510

Se: 1/1

Im: 108/300

Ax: I235.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Black Cherry 17" 14'

O BC-56-3

Acc:

2007 Jun 07

Acq Tm: 08:34:15

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Gum in Black Cherry**

HiSpeed CT/i

Ex: 25

HELICAL 10

Se: 1/4

Im: 46/60

Ax: 1225.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s/He

Lin:DCM / Lin:DCM / Id:ID

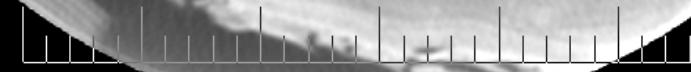
W:1500 L:-600

A

HiSpeed CTi  
CHERRY COOKIE  
O 05-02-07CC  
Acc:  
2007 May 02  
Acq Tm: 10:38:21

512 x 512  
STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Bark Inclusion in Hard Maple**

HiSpeed CT/i

Ex: 20534

Se: 1/1

Im: 1/185

Ax: S0.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-599

A

Purdue University at Pike Lumber

Walnut with Metal

O Walnut

Acc:

2007 Jun 15

Acq Tm: 16:54:02

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

**Nail in Black Walnut**

HiSpeed CT/i

Ex: 20534

Se: 1/1

Im: 16/185

Ax: I75.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-599

A

Purdue University at Pike Lumber

Walnut with Metal

O Walnut

Acc:

2007 Jun 15

Acq Tm: 16:54:02

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

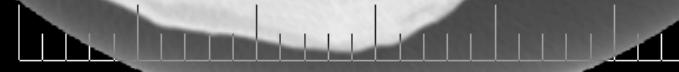
**Nail in Black Walnut**

HiSpeed CT/i  
Ex: 1004  
Helical Scan  
Se: 5/1  
Im: 185/880  
Ax: 120.0  
  
Mag: 1.6x

R

120.0 kV  
250.0 mA  
5.0 mm/1.0:1  
Tilt: 0.0  
1.0 s/He  
Lin:DCM / Lin:DCM / Id:ID  
W:1500 L:-600

A



P

HiSpeed CTi  
HARD MAPLE 14" 14'  
O HM-66-2  
Acc:  
2007 May 16  
Acq Tm: 10:24:16

512 x 512  
STANDARD

L

DFOV: 47.9 x 47.9cm

**Tap Hole in Hard Maple**

HiSpeed CT/i  
Ex: 1004  
Helical Scan  
Se: 5/1  
Im: 185/880  
Ax: 120.0  
Mag: 1.6x

R

120.0 kV  
250.0 mA  
5.0 mm/1.0:1  
Tilt: 0.0  
1.0 s/He  
Lin:DCM / Lin:DCM / Id:ID  
W:1500 L:-600

A

8.8 cm  
1.5 cm



P

HiSpeed CTi  
HARD MAPLE 14" 14'  
O HM-66-2  
Acc:  
2007 May 16  
Acq Tm: 10:24:16

512 x 512  
STANDARD

L

DFOV: 47.9 x 47.9cm

**Tap Whole in Hard Maple**

HiSpeed CT/i

Ex: 20514

Se: 1/1

Im: 198/320

Ax: 185.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Black Cherry 16" 16'

O BC-40-2

Acc:

2007 Jun 08

Acq Tm: 09:04:22

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**? In Black Cherry**

HiSpeed CT/i

Ex: 20534

Se: 1/1

Im: 170/185

Ax: I245.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-599

A

Purdue University at Pike Lumber

Walnut with Metal

○ Walnut

Acc:

2007 Jun 15

Acq Tm: 17:21:58

512 x 512

STANDARD

L

**Metal in Black Walnut**



DFOV: 47.9 x 47.9cm

HiSpeed CT/i

Ex: 24

RED OAK 2

Se: 4/9

Im: 21/80

Ax: 135.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

P

HiSpeed CTi

OAK 1A

O 05-01-07-2

Acc:

2007 May 01

Acq Tm: 16:59:54

512 x 512

STANDARD

L

DFOV: 47.9 x 47.9cm

**The Full Extent of Grubs in Red Oak**

HiSpeed CT/i

Ex: 20498

Se: 4/4

Im: 1/300

Ax: S0.0

Mag: 1.6x

R

120.0 kV

100.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-597

A

Purdue University at Pike Lumber

LUMBER

O LBR-1

Acc:

2007 Jun 01

Acq Tm: 17:39:09

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

# Random

HiSpeed CT/i

Ex: 20537

Se: 2/2

Im: 20/180

Ax: 195.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Hard Maple Burl

○ HM-Burl

Acc:

2007 Jun 19

Acq Tm: 14:25:15

512 x 512

STANDARD

L

Possible Curl

Possible Curl

P

DFOV: 47.9 x 47.9cm

**Curl**

HiSpeed CT/i

Ex: 20537

Se: 2/2

Im: 20/180

Ax: 195.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Hard Maple Burl

○ HM-Burl

Acc:

2007 Jun 19

Acq Tm: 14:25:15

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Curl**

HiSpeed CT/i

Ex: 20537

Se: 2/2

Im: 55/180

Ax: 1270.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Hard Maple Burl

○ HM-Burl

Acc:

2007 Jun 19

Acq Tm: 14:25:15

512 x 512

STANDARD

L

P

DFOV: 47.9 x 47.9cm

**Spalting**

HiSpeed CT/i

Ex: 24

Se: 116/9

Im: 40/80

Cor: P31.4

Mag: 1.6x

R

120.0 kV

250.0 mA

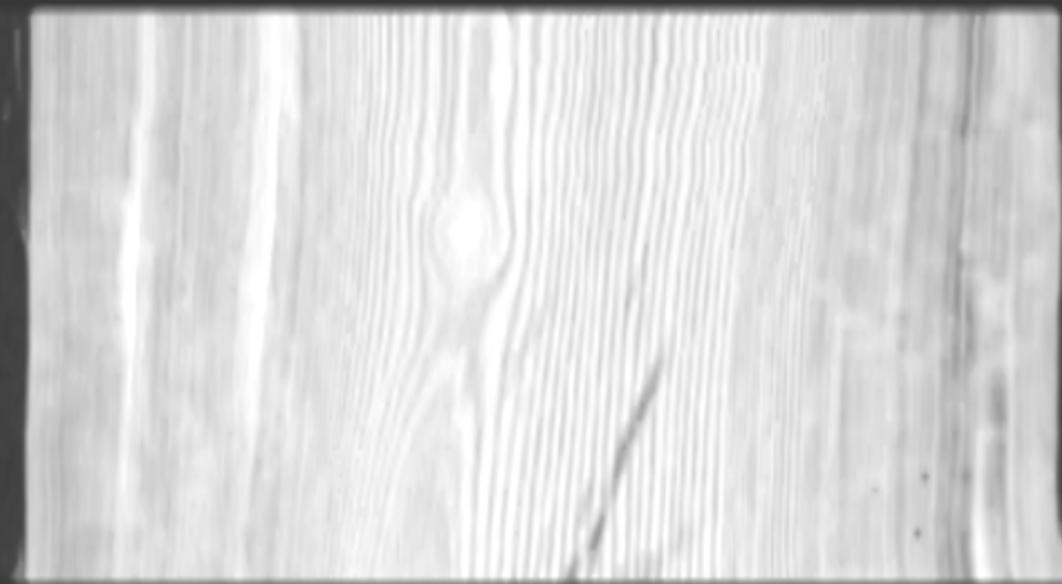
Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

S



HiSpeed CTi

OAK 1A

O 05-01-07-2

Acc:

2007 May 01

Acq Tm: 15:31:33

512x512

STANDARD

L

DFOV: 39.9 x 39.9cm



HiSpeed CT/i

Ex: 20536

Se: 2/2

Im: 69/240

Ax: 140.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

Walnut Sycamore Beech Ash

O Species Gallery

Acc:

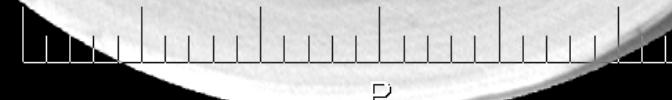
2007 Jun 18

Acq Tm: 17:44:44

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Sycamore**

HiSpeed CT/i

Ex: 20529

Se: 1/1

Im: 372/565

Ax: 155.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber

White Oak 14" 16'

O WO-81-3

Acc:

2007 Jun 14

Acq Tm: 14:47:19

512 x 512

STANDARD

L

Growth Rings  
Pith  
Late Wood  
Early Wood



P

DFOV: 47.9 x 47.9cm

**Features**

HiSpeed CT/i

Ex: 20538

Se: 3/3

Im: 347/600

Ax: 1230.0

Mag: 1.6x

R

120.0 kV

250.0 mA

5.0 mm/1.0:1

Tilt: 0.0

1.0 s

Lin:DCM / Lin:DCM / Id:ID

W:1500 L:-600

A

Purdue University at Pike Lumber  
Black Walnut Veneer Log

O BW-V

Acc:

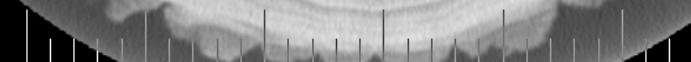
2007 Jun 19

Acq Tm: 17:14:31

512 x 512

STANDARD

L



P

DFOV: 47.9 x 47.9cm

**Black Walnut**



**Hardwood Scanning Center**



# **Innovations in Wood Processing**

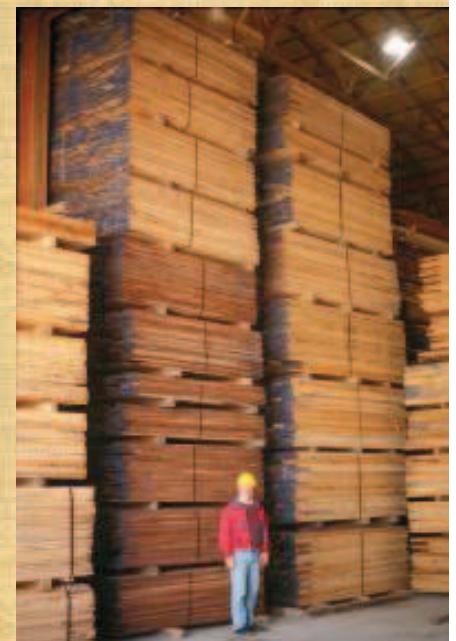
**Rado Gazo**

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



# **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  $-300^{\circ}\text{F}$  ( $-149^{\circ}\text{C}$ ), 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  $300^{\circ}\text{F}$  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

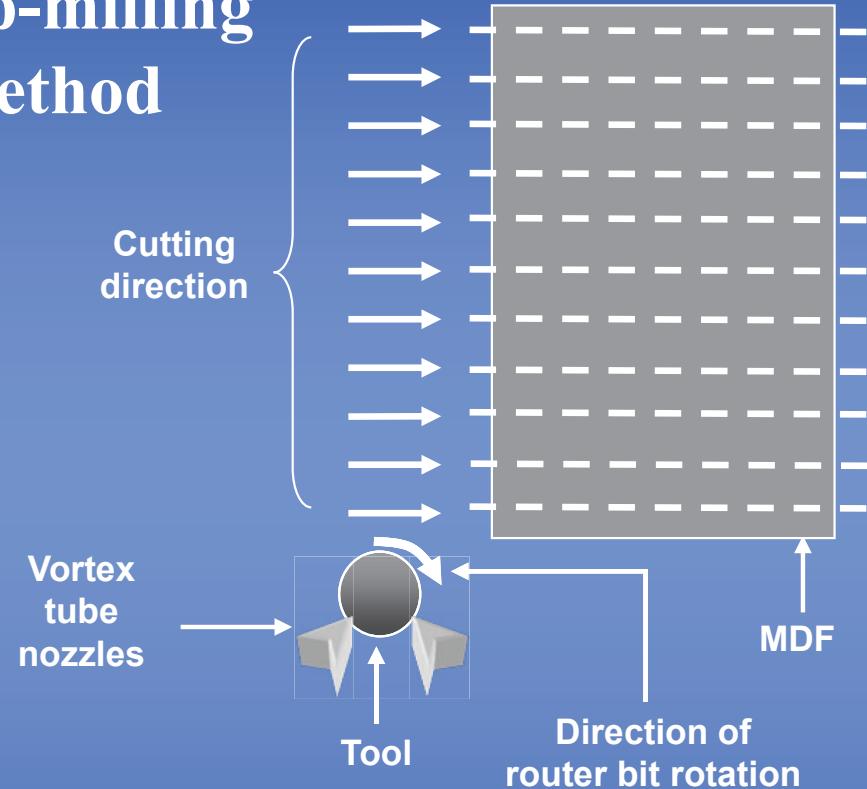
## Materials:

- 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:  $\frac{3}{4}$ " (19.05 mm)



# Methodology

## Up-milling Method



- 360 complete passes/sheet
- 166,000 m (103 miles) length of cut per flute
- $\frac{1}{4}$ " (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 )

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

$$N = \text{RPM} = 16,000;$$

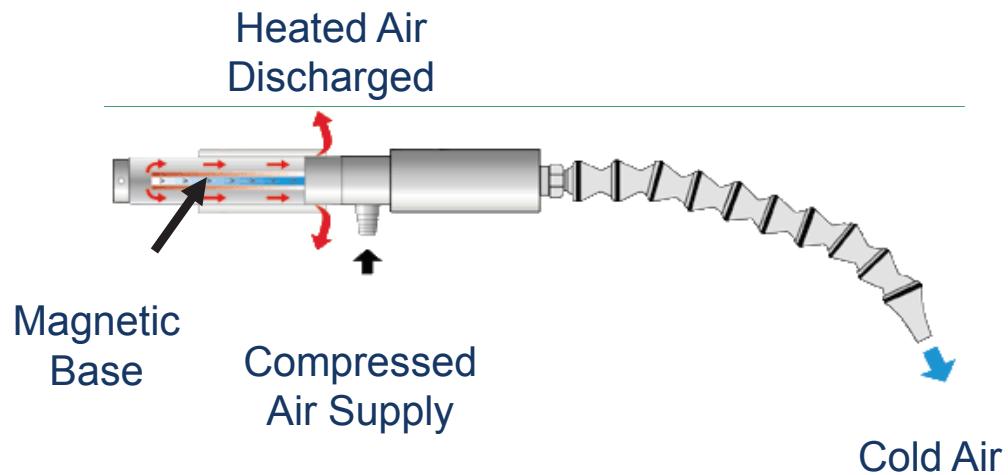
$$Z = \# \text{ knives} = 2$$

$$S_z = \text{cut per tooth} = 0.012 \text{ to } 0.015 \text{ inches}$$

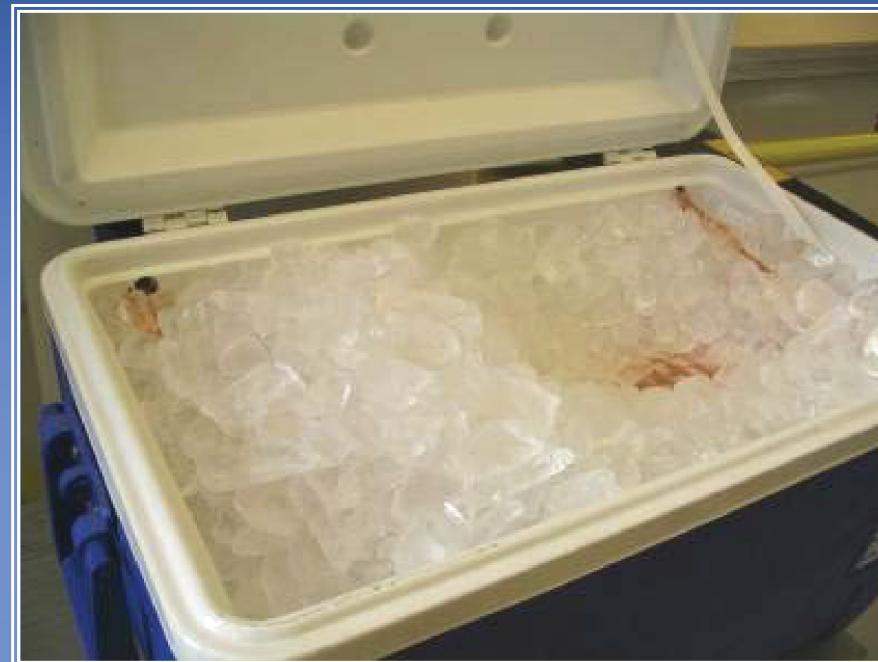


**Incoming Air** 90°F  
**Cold Gun** -50°F  
**Resulting Temp.** 40°F (4.4°C)

## How the vortex tube works



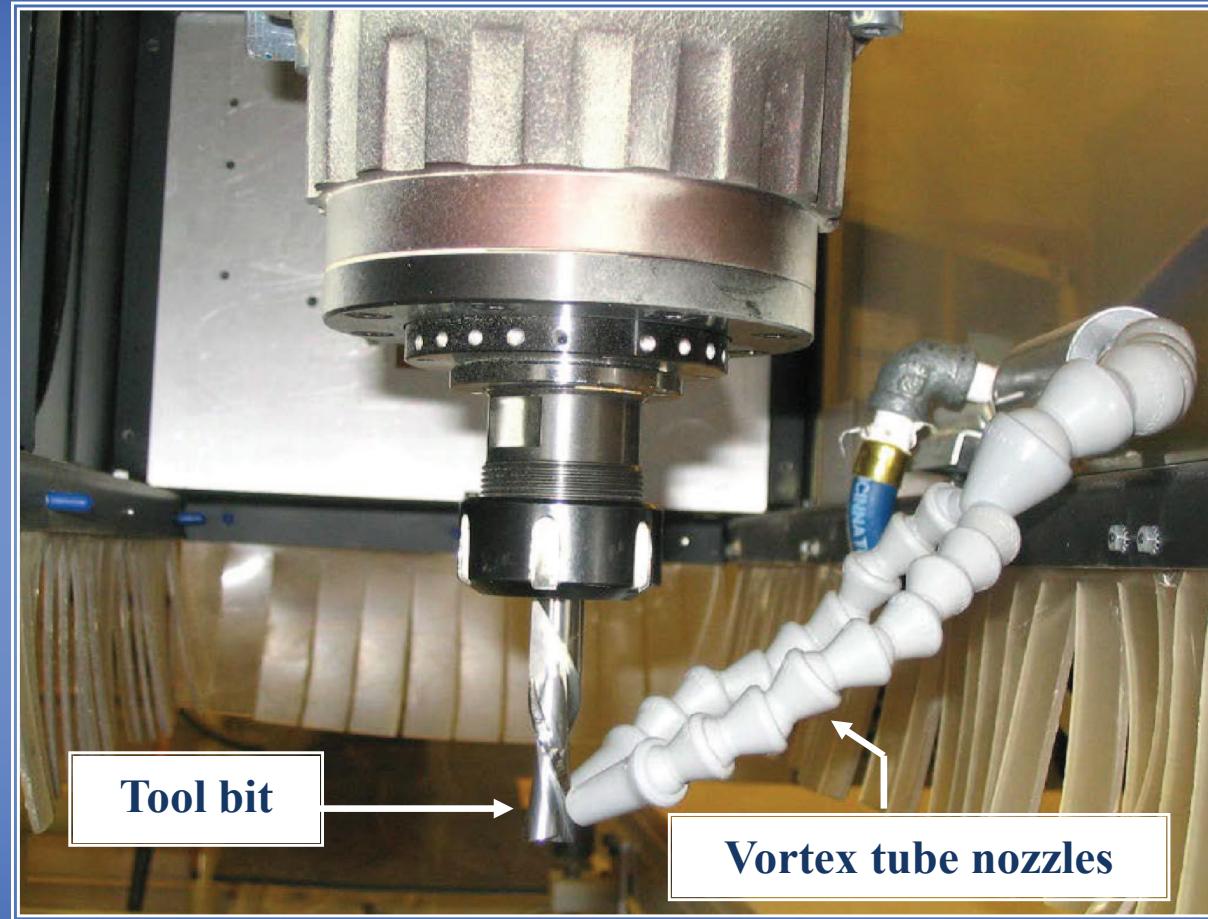
The cold gun reduces temperature of incoming compressed air by about 50° Fahrenheit



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

**Resulting Temp. 20°F (-6.7°C)**

# Methodology



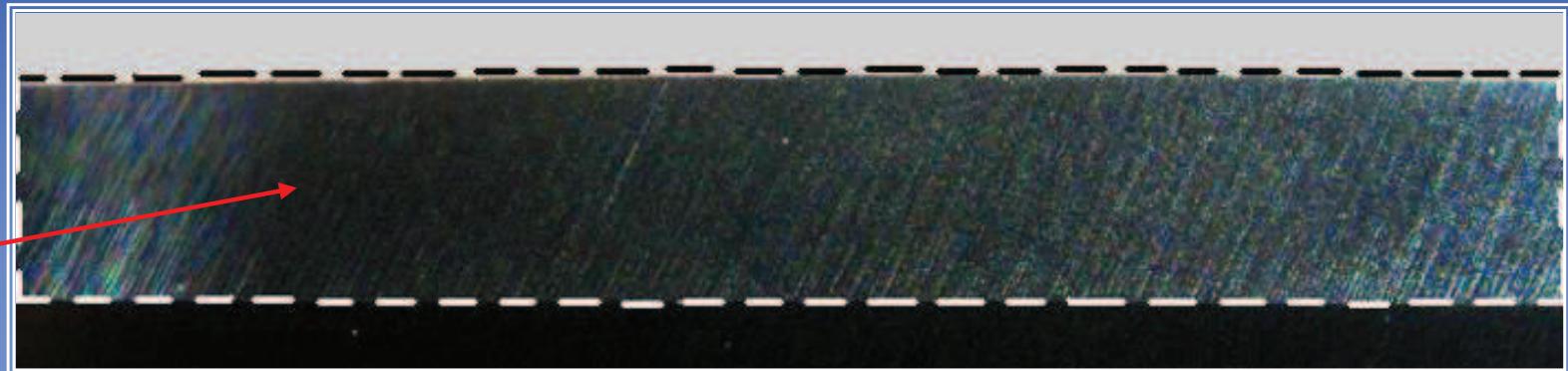
Placement of vortex tube in relation to the router bit

# Methodology

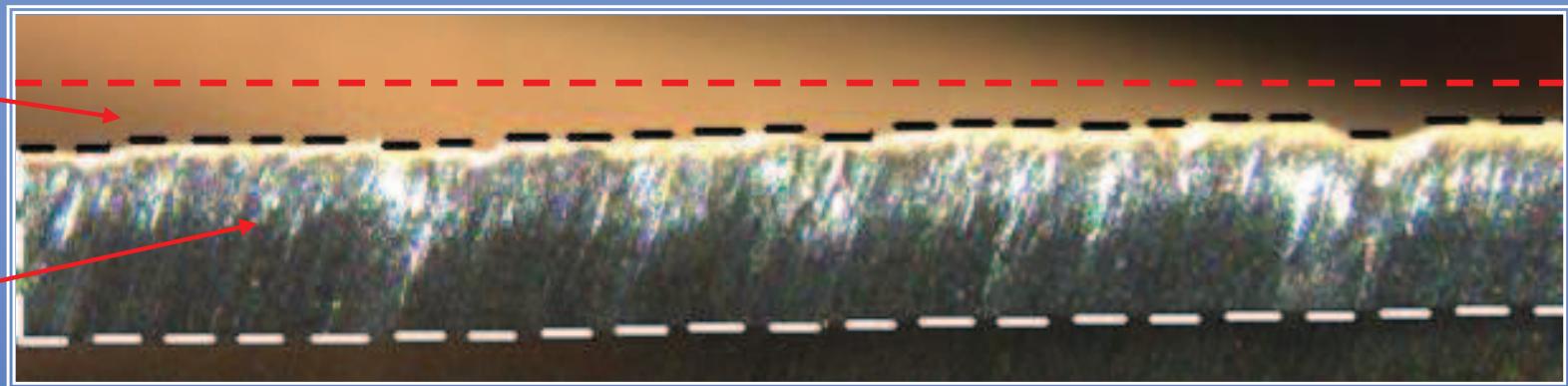
- Power data (Amp, kW) were measured throughout the cutting process
- Sound level (dB) measurement
- A visual assessment of MDF edge surface by a panel of five judges

# Methodology

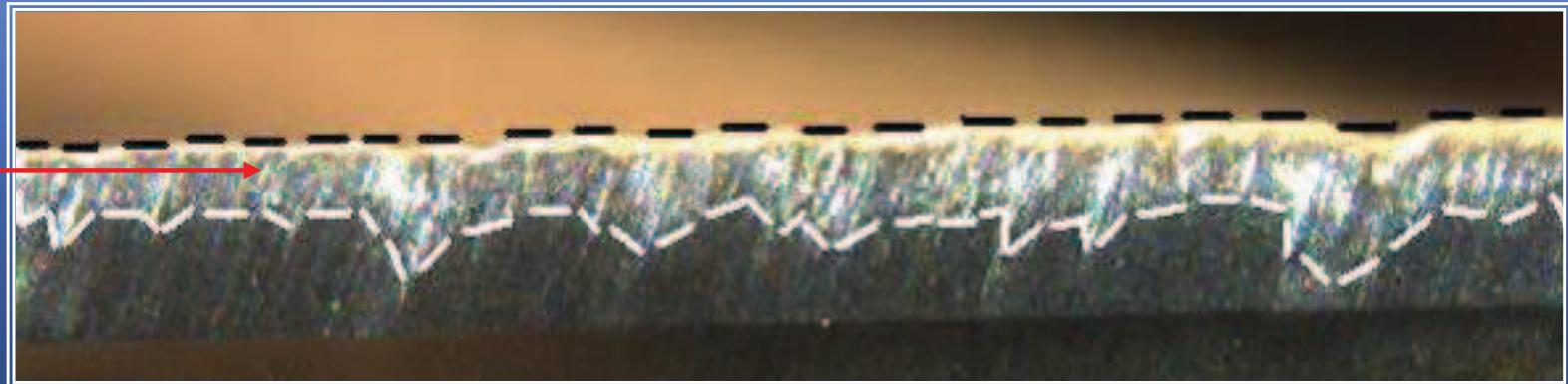
Original area



Wear Void



Remaining area



Wear Scar

# 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 <i>p</i> = 0.006*	Wear scar <i>p</i> = <.0001*	Total wear <i>p</i> = <.0001*
	(°C)	(%)	(%)	(%)
Untreated	21.0	32.07 <sup>a</sup>	44.09 <sup>a</sup>	76.16 <sup>a</sup>
Treated	21.0	20.71 <sup>b</sup>	25.31 <sup>b</sup>	46.02 <sup>b</sup>

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

\*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 (°C)	Wear void p = 0.225*	Wear scar p = 0.006*	Total wear p = 0.025*
	(%)	(%)	(%)
21.0	20.71 <sup>a</sup>	25.31 <sup>a</sup>	46.02 <sup>a</sup>
4.4	17.86 <sup>a</sup>	23.41 <sup>b</sup>	41.27 <sup>b</sup>
-6.7	16.13 <sup>a</sup>	18.96 <sup>a</sup>	35.09 <sup>b</sup>

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

Statistical results were calculated with Two-way ANOVA

# Tool Surface Microstructure (Magnification. 5400X)

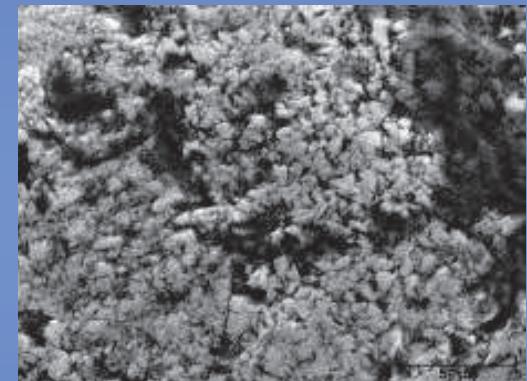
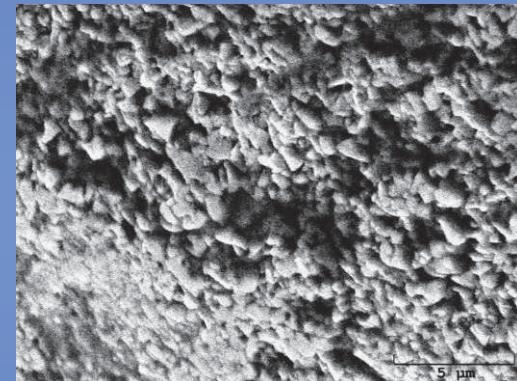
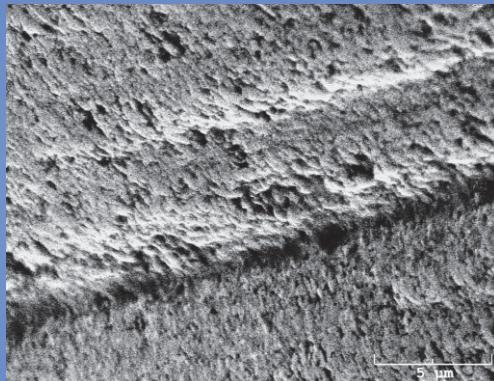
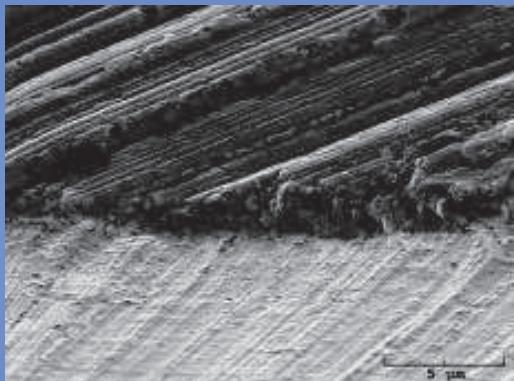
Unused

70°F(21°C)

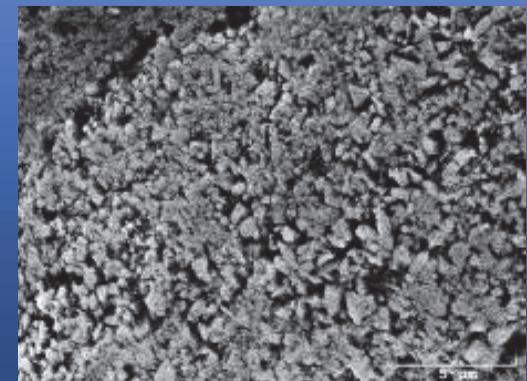
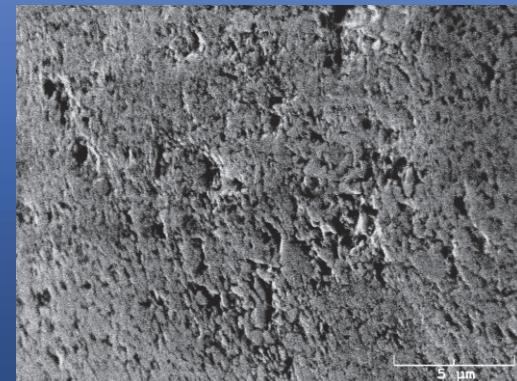
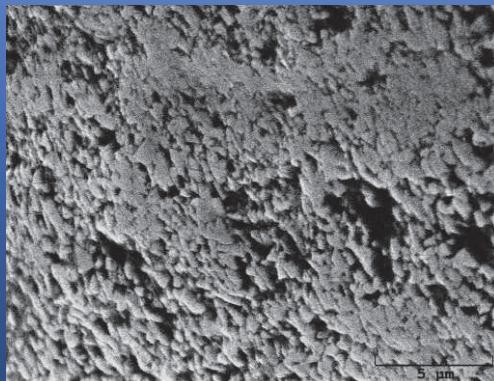
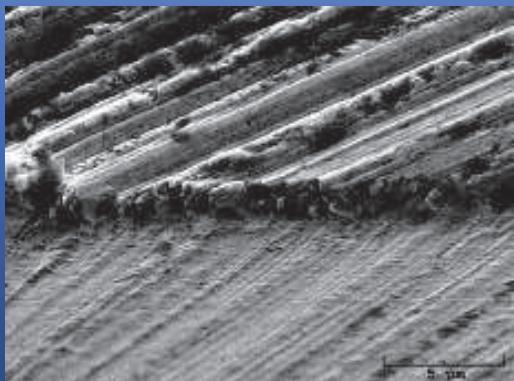
40°F(4.4°C)

20°F(-6.7°C)

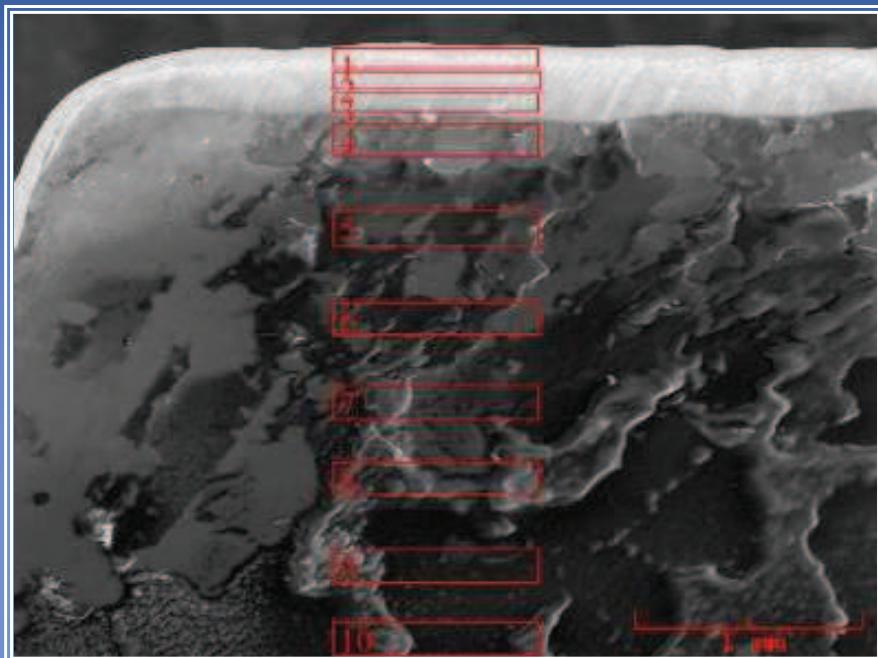
Untreated



Cryogenically treated



# Results and Discussion - Energy-dispersive spectroscopy



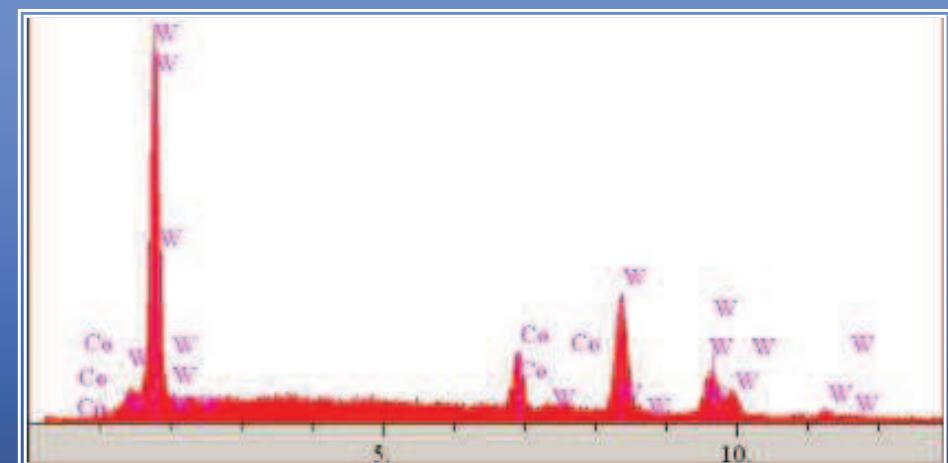
Element	1	2	3	4	5	6	7	8	9	10
	(wt. %)									
Nitrogen	0.16	0.6	0.2	0.5	0.6	1.15	0.57	2.29	3.76	0
Oxygen	0.05	0.19	0.18	0.52	0.26	0.71	0.52	1.16	1.09	5.6
Sodium	0.04	0.02	0.02	0.03	0.1	0.1	0.11	0.14	0.26	0.4
Phosphorus	0.62	0.07	0.14	0.02	0	0.6	0.26	0.35	0.77	1.59
Sulphur	0.92	0.46	0.51	0.1	0.28	0.17	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
Potassium	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

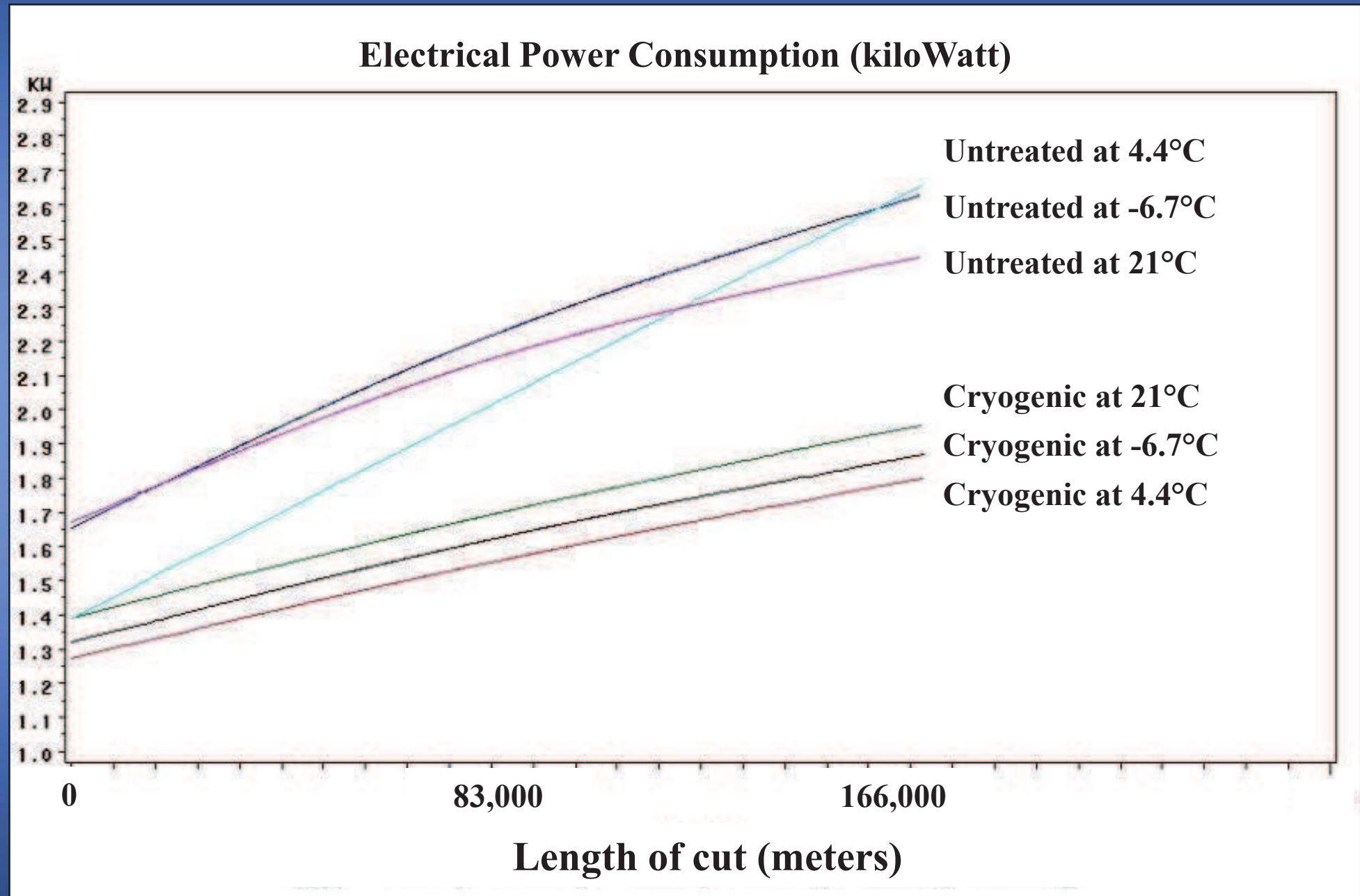
S – glue catalyst, wood

Cl, Na – adhesive extender, catalyst

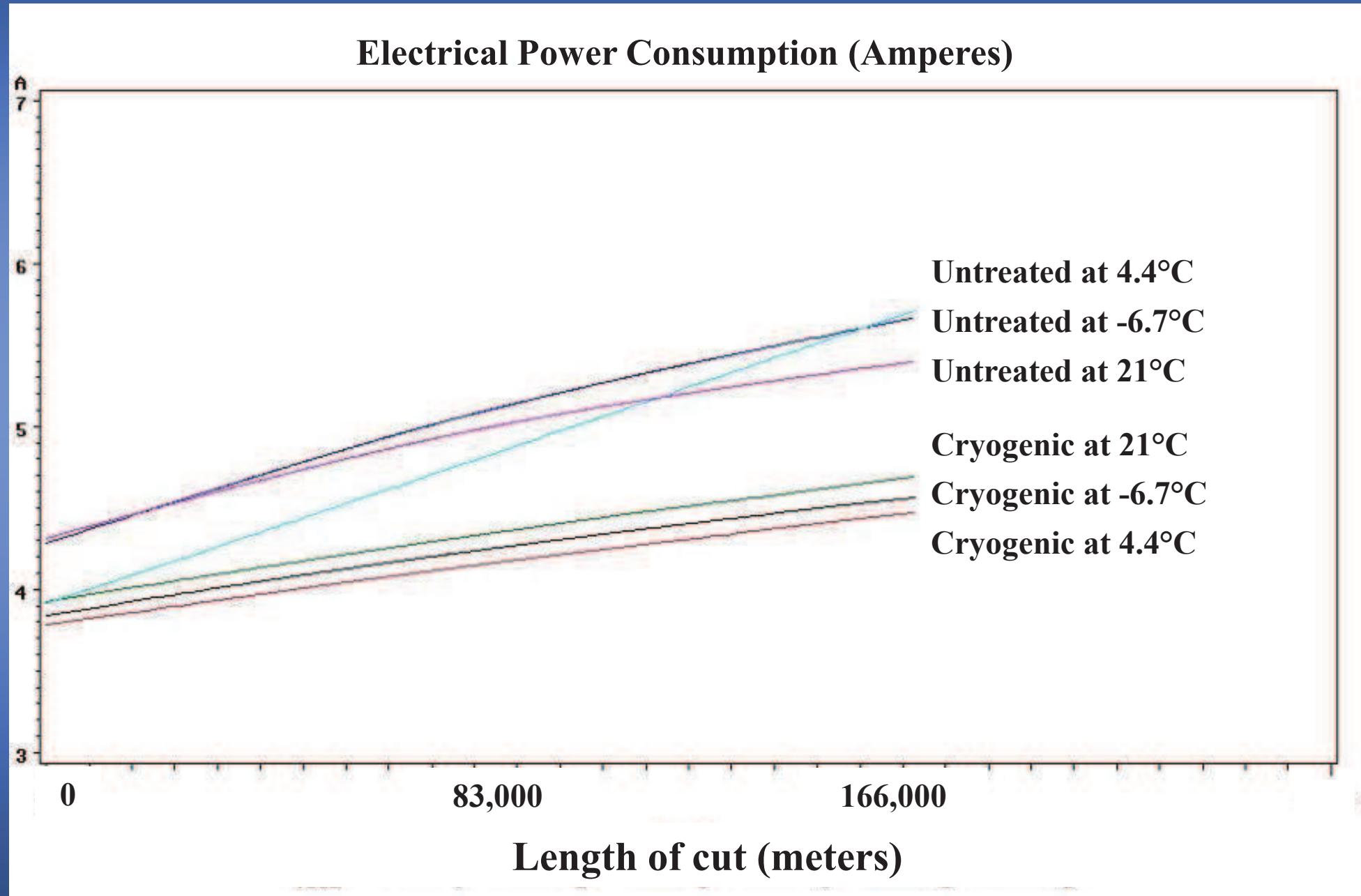


Nitration, halogenation, sulfidation, oxidation – high temp phenomena indicators

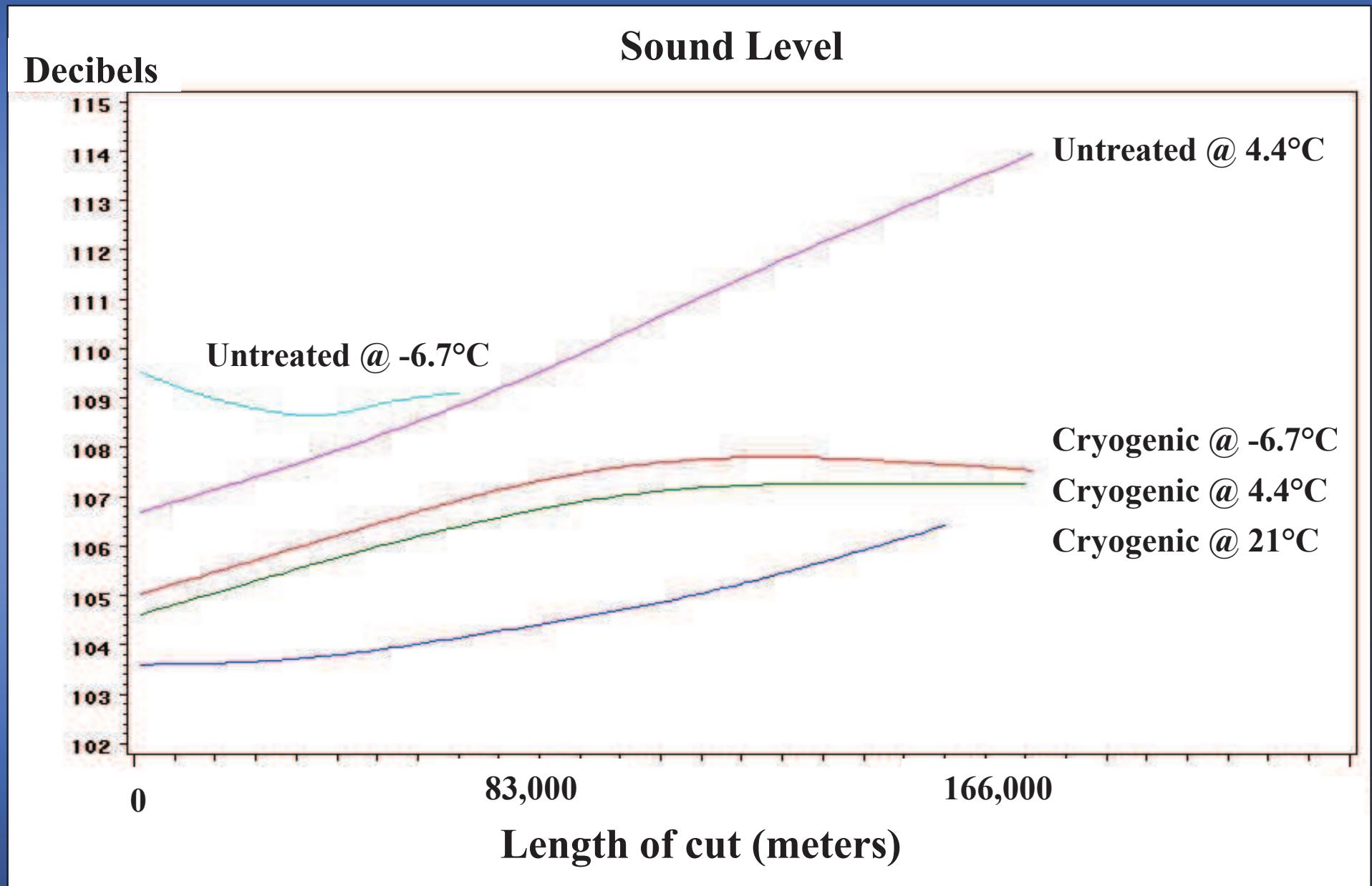
# Results and Discussion



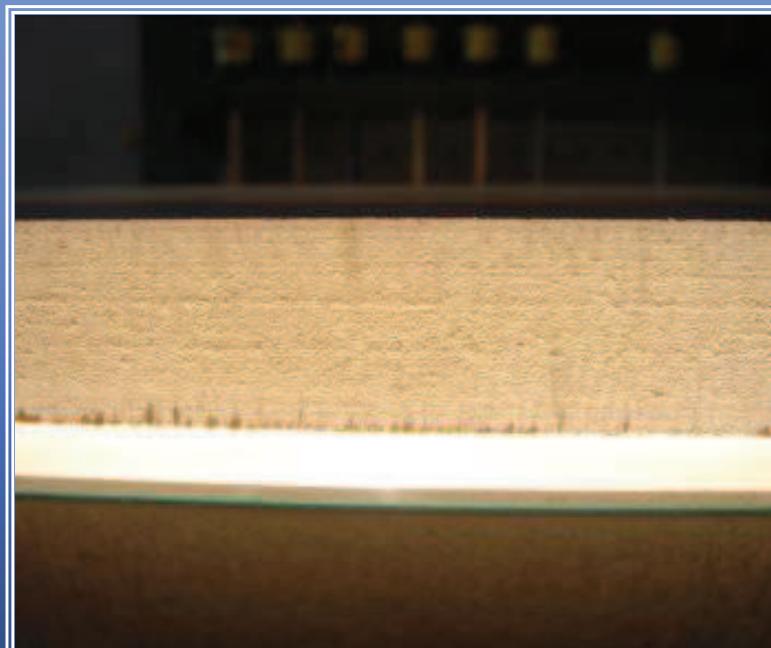
# Results and Discussion



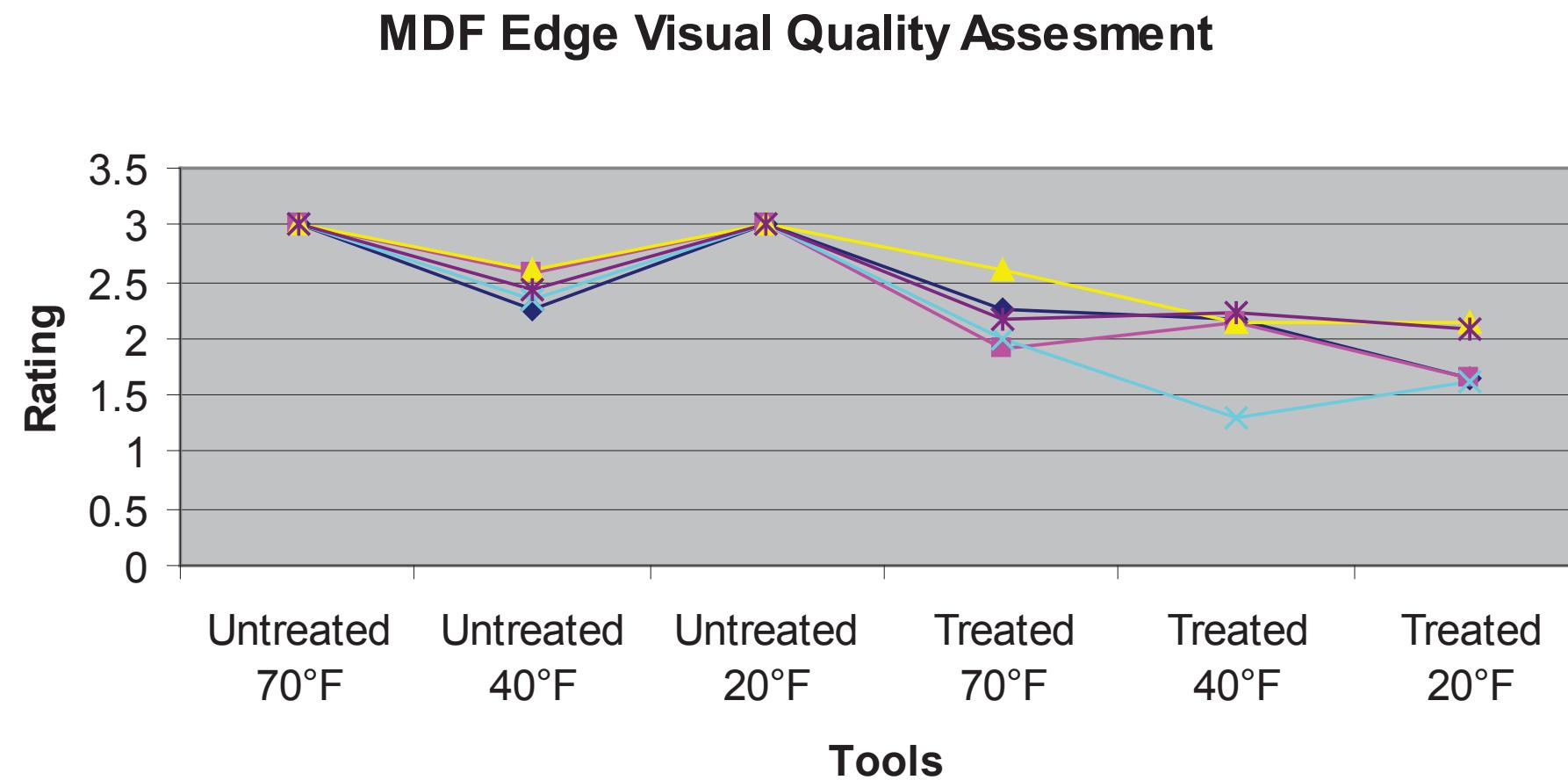
# Results and Discussion



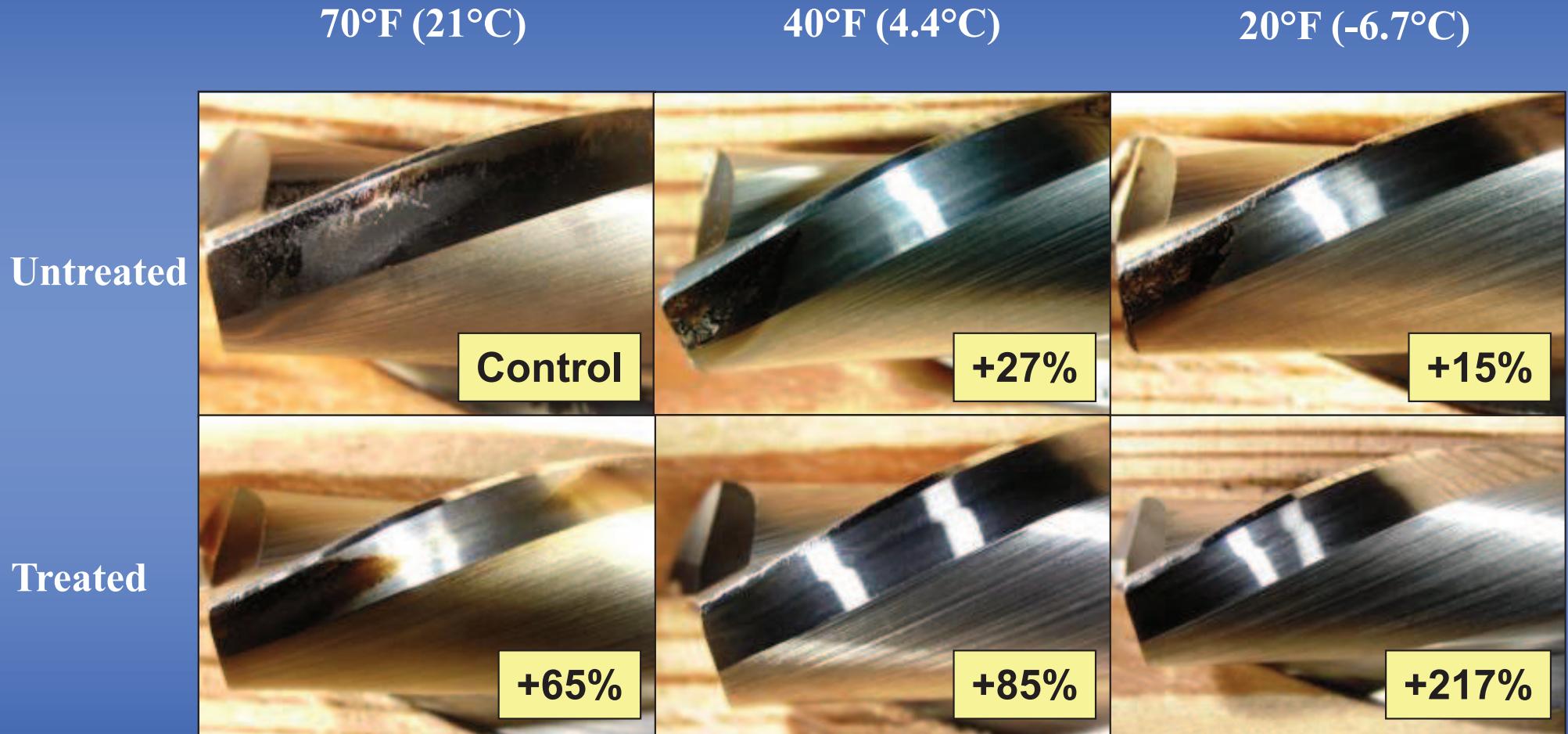
# Results and Discussion



# Results and Discussion



# Conclusions



Estimated increase in tool life

# Primary Wood Processing

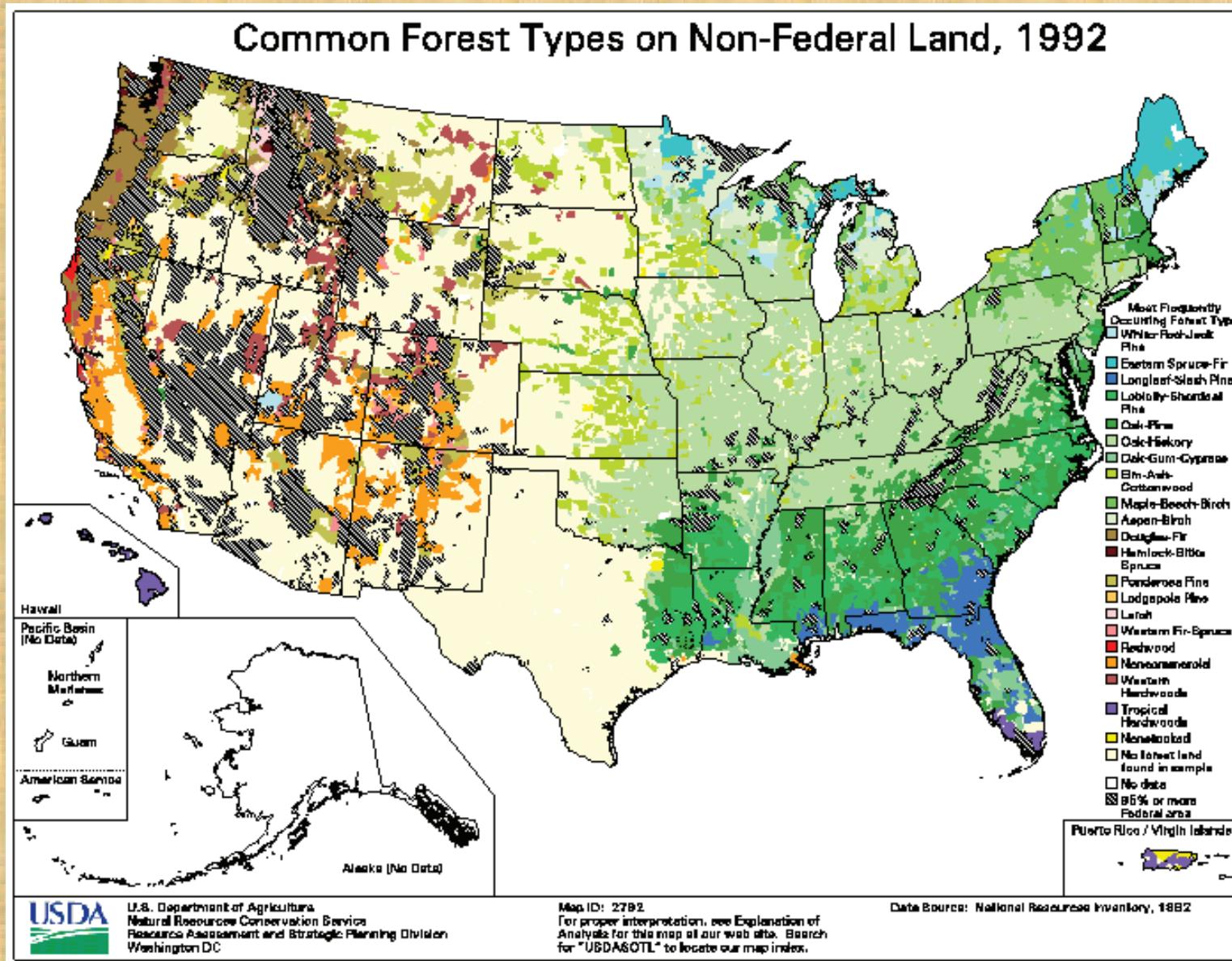
**Example: CT Scanning of Logs**

# Past scanning studies

Numerous past research studies have examined log breakdown value improvements.

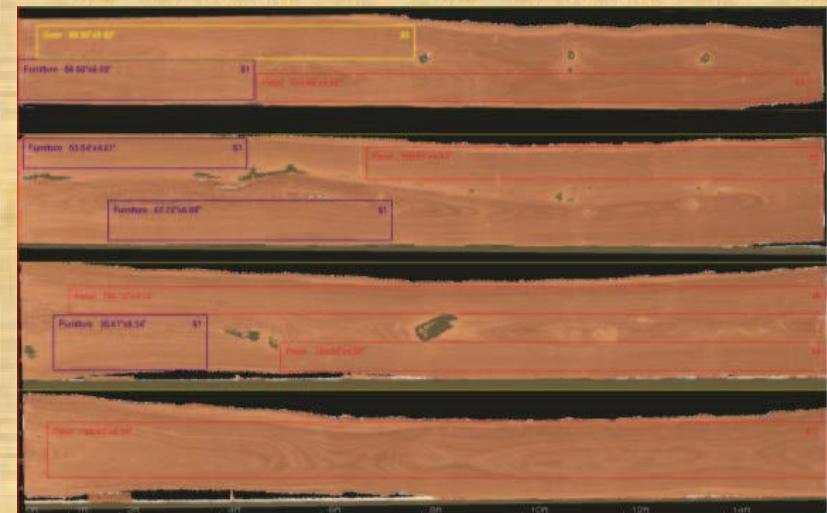
Year	Author	# of Logs	Species	% Improvement
1962	Peter	10	Southern Pine	3%
1967	Peter	50	Yellow Poplar	9%
1969	Tsolakides	6	Red Oak	21%
1975	Wagner and Taylor	10	Southern Pine	8%
1980	Richards <i>et al.</i>	320	Red Oak	11%
1989	Steele <i>et al.</i>	24	Red Oak	12%
1994	Steele <i>et al.</i>	6	Red Oak	10%
'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

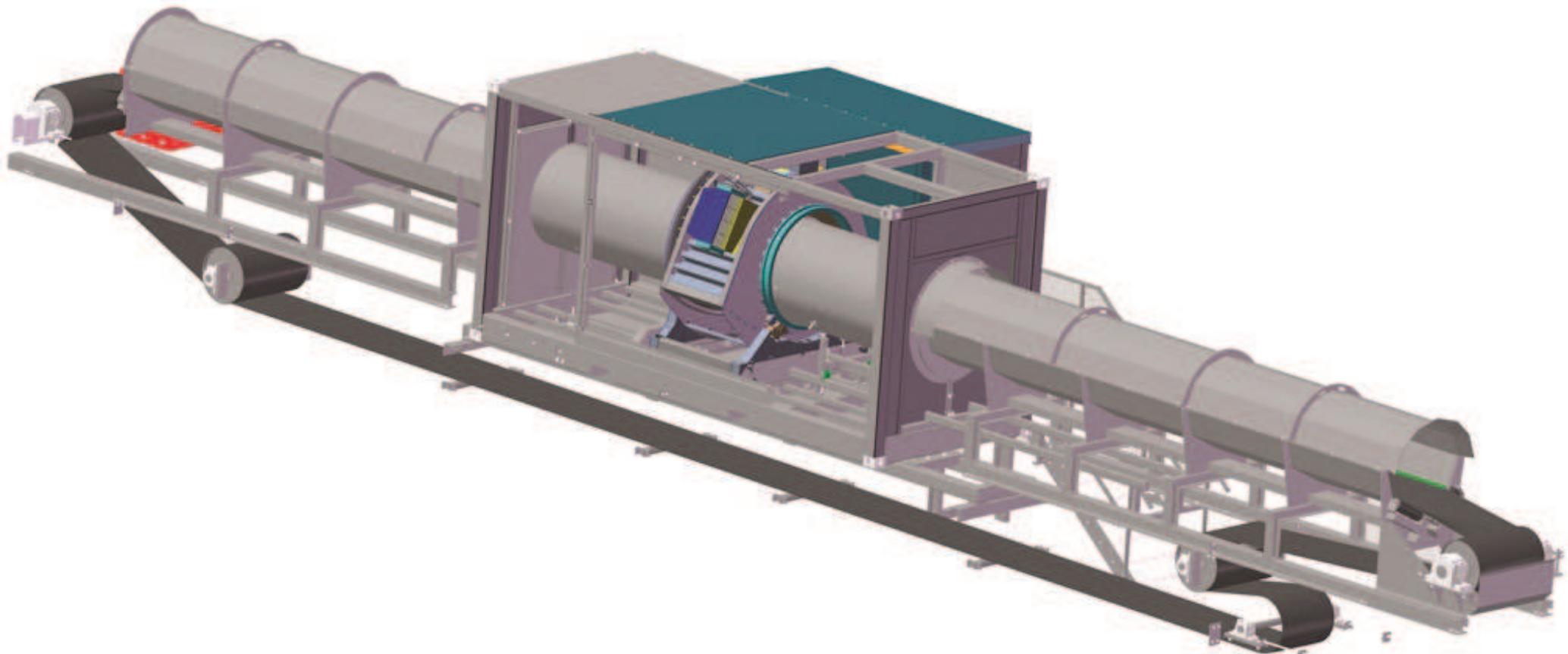


# Results – Sawmill vs. CT Scanner

Gain (%)	Black Cherry	Hard Maple	Red Oak	White Oak	Yellow Poplar	Overall
All Grades	42	33	24	60	87	<b>46</b>
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**<sup>®</sup>  
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**<sup>®</sup>  
INNOVATING WOOD

**CT.LOG**

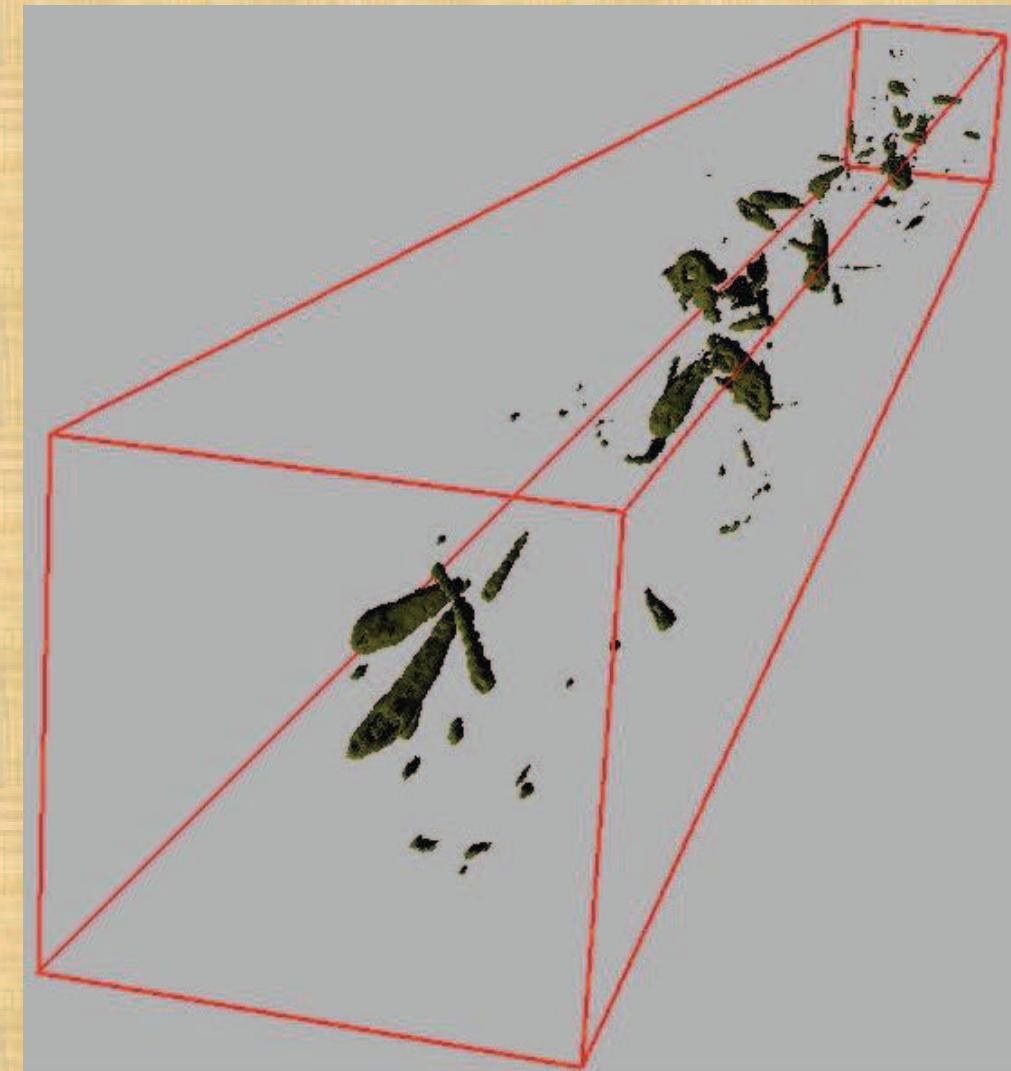
CT LOG

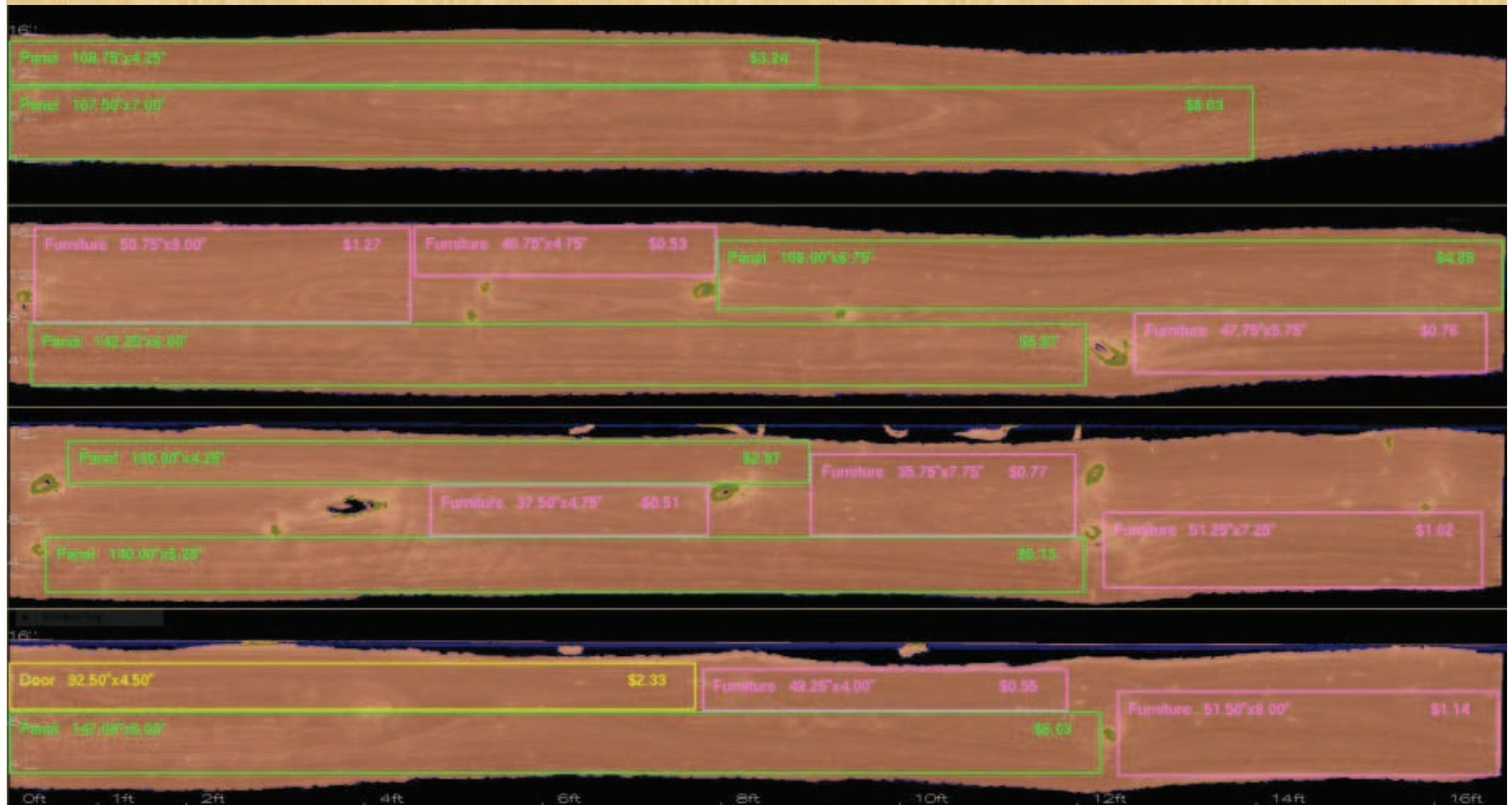
MICROTEC

# Software Development

- LogView
  - Veneer (full optimization)
  - Sawmill (full optimization)
- Developed by Purdue University Hardwood Scanning Center
- Commercialized by LogView, LLC

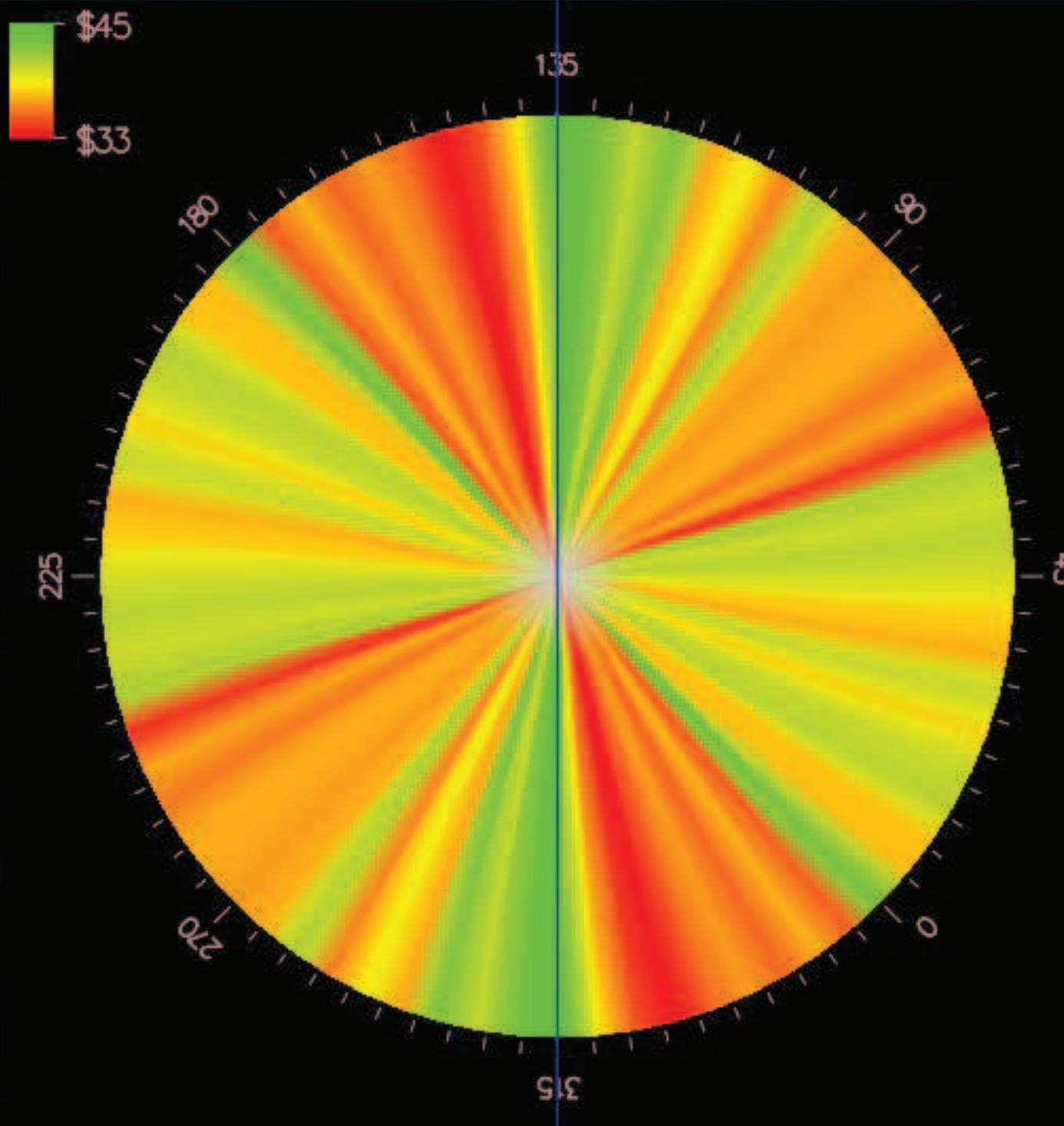


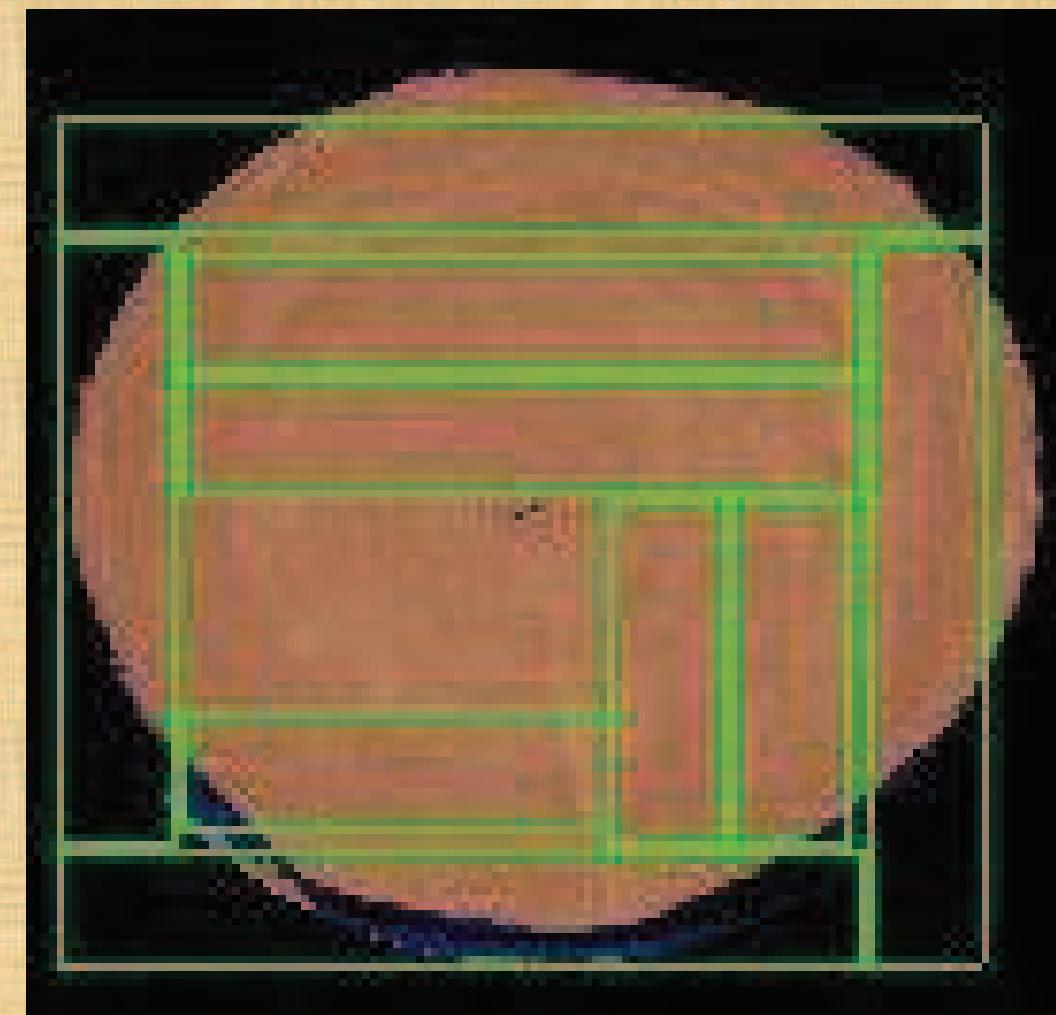
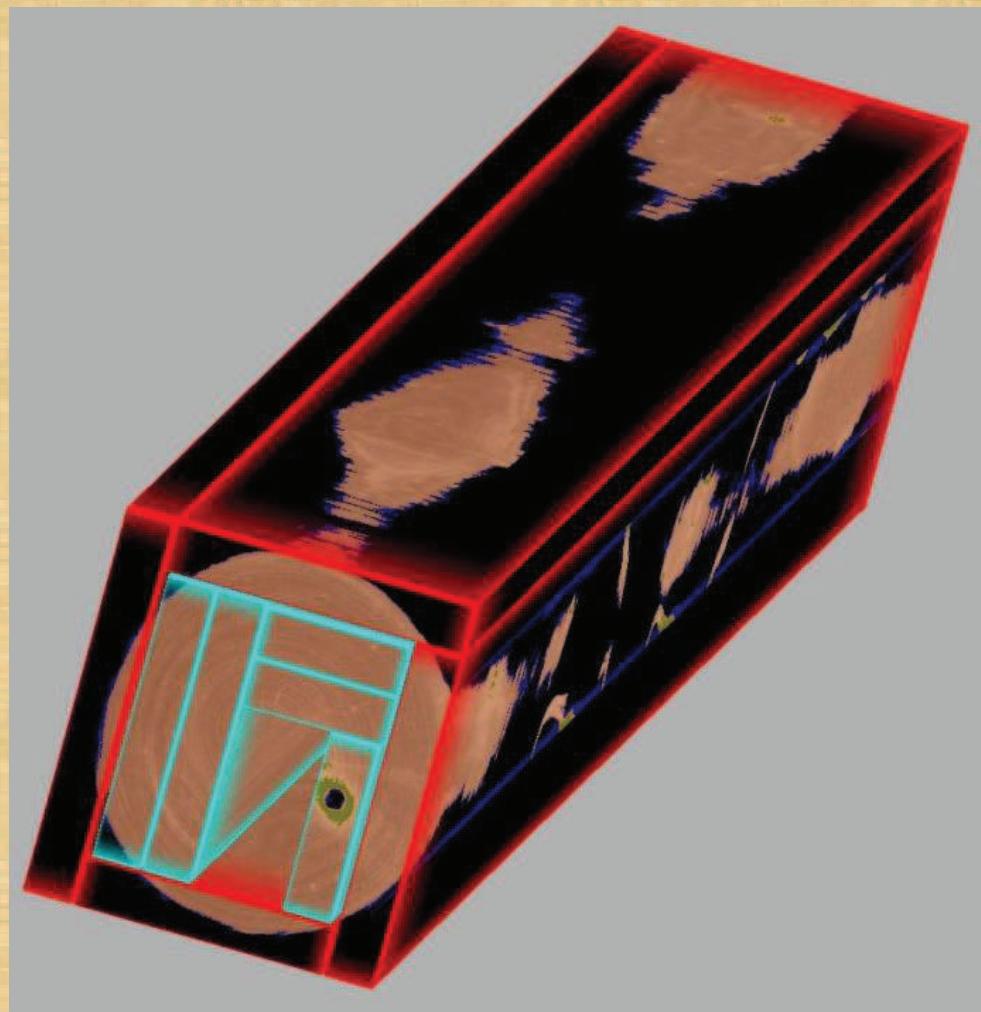




## Analysis Results

X







# 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