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Forest Service

**Technology &
Development
Program**

2400—Timber
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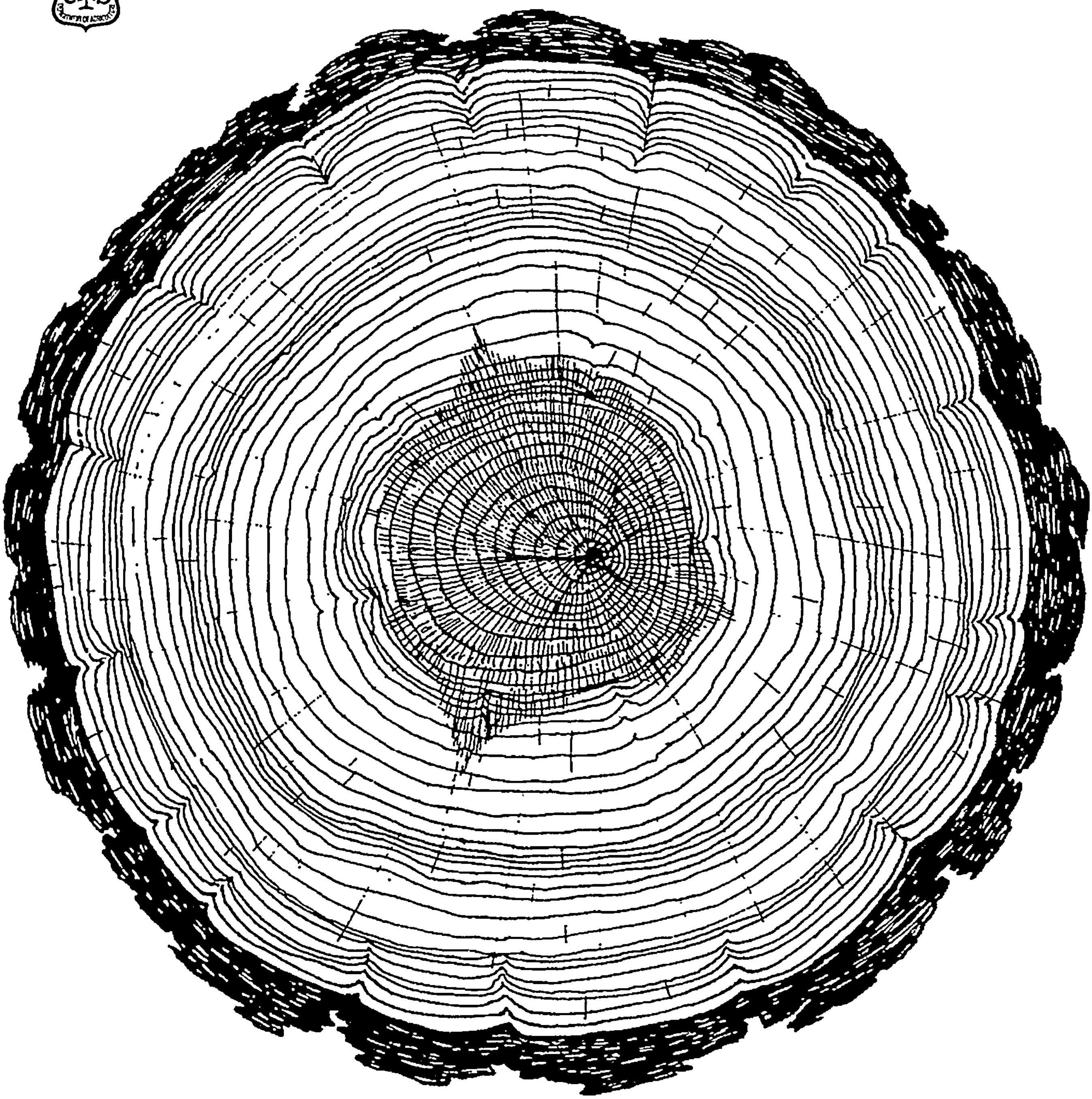
Detection of Foreign Objects in Logs —Demonstration Test



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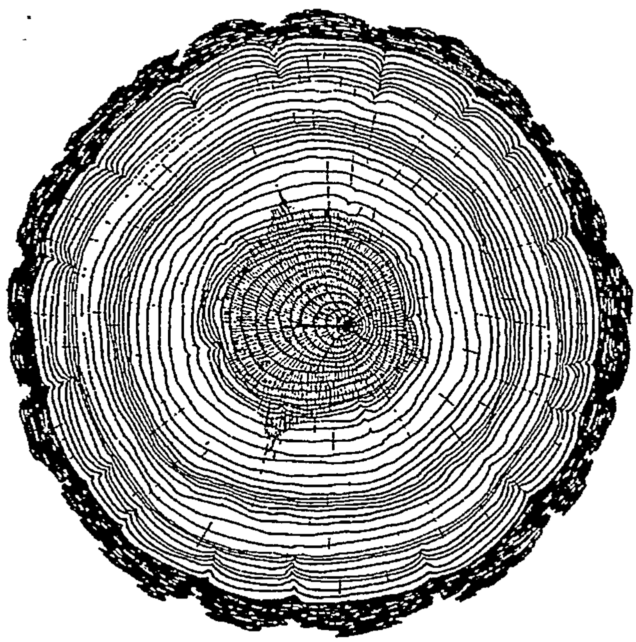

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Technology & Development Program
San Dimas, California

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Foreign Object Detection

December 1992

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FORWARD

This publication is a result of the Detection of Foreign Objects Project at the San Dimas Technology and Development Center.

This project was initiated by the Forest Product Sales Technology Committtee. This group meets yearly to discuss field needs in the area of forest product sales, ranging from the initial sale layout to the transport of products. Work is prioritized and future projects are developed to address needs which appear to be multi-regional in scope.

Field personnel who see a need for information to be distributed, have ideas for new product development, or the application of new technology, are encoraged to contact their Regional representitive on this committee. The current representitives are:

Bill Carr R01A
Ray Walker R02A
Alan Lucas R03A
Jim Ragland R04A
Dennis Caird R05A
Don Studier R06F12A
Jim Sherar R08F11A
Ken Shalda R09A
Al Aitken R10A

Bob Simonson
Program Leader—Timber

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INTRODUCTION

Foreign objects embedded in trees have been a persistent problem for the forest products industry. Most of these objects are hidden from view because of new growth; they cannot be visually detected. When a chain saw, axe, or sawmill blade encounters a hidden foreign object, equipment downtime may occur and—more seriously—personnel may be injured. This adversely effects the value of the stumpage. The sawmills are, to a degree, protected from metallic objects because of the use of inductive loop instrumentation. However, with the advent of lower stump height allowances, increasing utilization standards, and the increasing use of mechanical shears, there has been a significant increase in the incidence of rocks in the butt logs. In addition, rock cores and ceramic spikes have been embedded in National Forest trees to avoid metal-detection hardware and cause damage and downtime for mills in the name of environmentalism.

Due to the rising number of incidents of nonmetallic embedded objects, the State of California's Occupational, Health and Safety Standards Board recently passed a resolution calling for a change in wording of standards from "metallic objects" to "foreign objects" to protect mill workers. In response to this situation, the Forest Products Technology Committee determined that the feasibility of detecting foreign objects in trees should be investigated and in 1990 assigned this task to the San Dimas Technology and Development Center (SDTDC).

SDTDC engineers and industry representative involved in nondestructive testing ran tests using off-the-shelf portable X-ray, sonar, and radar techniques. These proved unsuccessful in the field (fig. 1) due to the lack of power and image enhancement. Faced with these limitations, the Technology Committee changed the project objective to determine the feasibility of detecting foreign objects in logs at the mill site, rather than in standing trees.

SDTDC engineers discovered that manufacturers of metal detection equipment did not possess R&D capability in the desired area. SDTDC also found that other organizations were experimenting with the use of nondestructive testing techniques to examine logs for defects, knots, and ring patterns. These techniques use high-power X-rays and nuclear magnetic resonance methods. Although most efforts were barely beyond the conceptual testing phase, one organization (located in Canada) had reached the prototype stage and looked promising.

MacMillan Bloedel Research Ltd. had built an X-ray scanner and developed image enhancement and analysis software that successfully improved yield by optimizing saw patterns based on the location of knots in the log. Tests had been successful on a limited number of species of smaller diameter logs when scanned at conveyor speeds typical of a sawmill operation. Since SDTDC engineers had concluded that X-rays were the most practical and economic non-destructive testing method for detecting all types of foreign objects in logs, an agreement was reached with MacMillan Bloedel Research to utilize their prototype facility on Vancouver Island to test for a solution to the Forest Service problem.

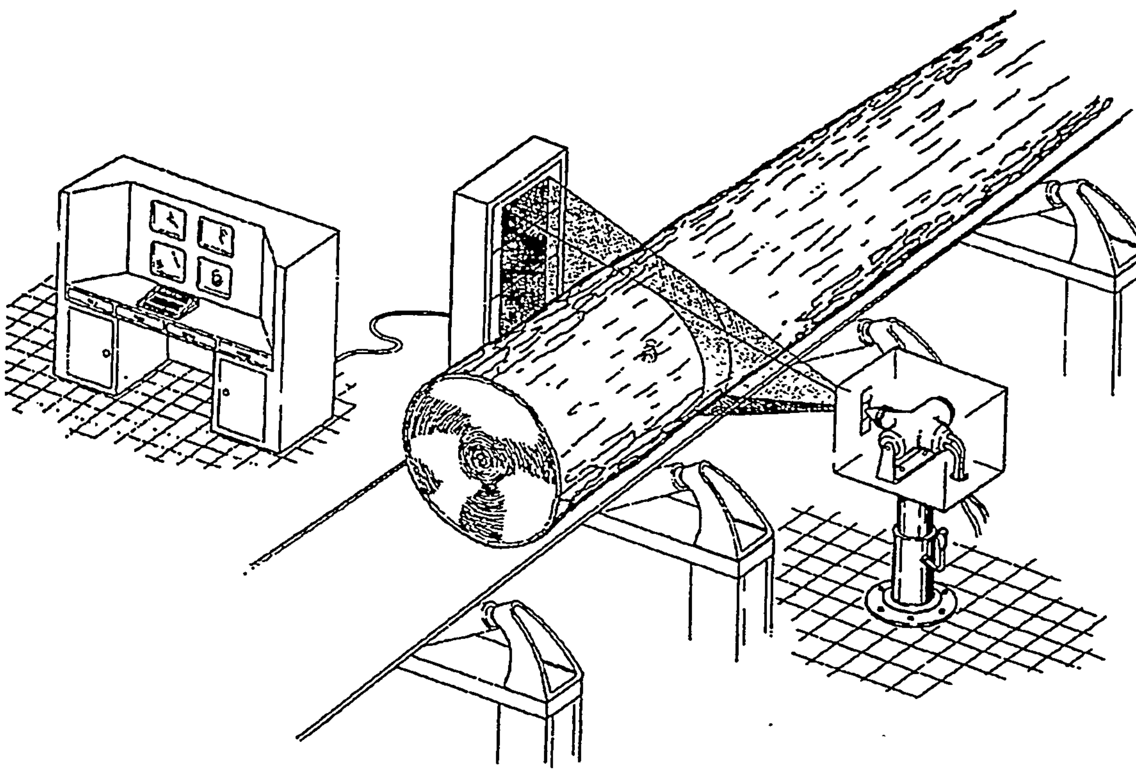


Figure 1. Semiportable X-ray system.

TEST OBJECTIVE

The objective of the test was to demonstrate the feasibility of employing X-ray scanners and image enhancement techniques to detect foreign objects embedded in logs traveling at typical sawmill conveyor speeds.

TEST PROCEDURE

A senior research scientist; logging, mechanical, and electronic engineers; a wood technologist; and a senior research technician were involved in the preparation and execution of this test.

Go-no-go test criteria were prepared to minimize the number of test runs needed. A run was considered successful if the largest nonmetallic object (a rock core) was clearly visible in one or more views on the test site monitor. Raw data files of each run were stored on tape for later analysis consisting primarily of the use of image enhancement techniques to obtain an optimum display of the objects on a color monitor. Images of selected runs were hard copy recorded by taking photographs of the display monitor and/or sending the image to a black-and-white laser printer.

Four logs (two Douglas Fir, one Hemlock, and one Red Cedar) with bark in place (fig. 2) were chosen to be tested. They had been previously harvested, transported to the log pond, and then removed from the pond a few days prior to testing. These logs were then cut to 8-foot lengths, scaled, numbered, and marked with a coordinate system. Samples were removed from each log for oven-dry analysis of specific gravity and moisture content. The logs used in this test were as follows:

Log No	Species	Diameter (in) (lg end/sm end)	Dry density (lb/cu ft)	Moisture content (lb/cu ft)
1	Douglas Fir	36/3	34	9.0
2	Hemlock	31/30	25	35.5
3	Red Cedar	42/41	19	16.0
4	Douglas Fir	44/39	36	13.2

Several different *foreign objects* (fig. 3) were embedded at eight identical locations in each log as follows:

1. *Barbed wire,* 6 inches in length, was inserted at the base of the log in a 3/8-inch diameter hole drilled 12-inches deep along the major axis of the log, 3 inches from the cambium layer.

Figure 2. Three of the test logs.

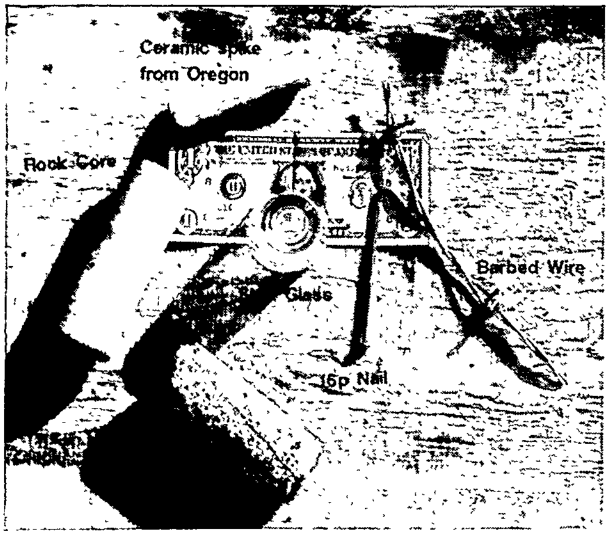


Figure 3. Five of the seven objects used in tests.

The remaining objects were inserted into the logs along a line, drawn parallel to the log center, on the bark surface. Except for the driven nail, the objects were placed at the bottom of holes drilled radially towards the log center. After object placement, each hole was backfilled with wood chip material, which was then compacted.

2. *Barbed wire*, 6 inches in length, was inserted 2 feet from the base, into a hole 9-inches deep and 3/8-inch in diameter.

3. A *rock core*, 4-inches long and 1-1/2 inches in diameter, was inserted 3 feet from the base, into a hole 9-inches deep and 1-1/2 inches in diameter.

4. A *shot glass* (to simulate a glass insulator), 1-1/2 inches in diameter, was inserted 4 feet from the base, into a hole 6-inches deep and 1-1/2 inches in diameter. The glass was wedged into place with wooden shims prior to backfilling.

5. A *glass marble*, 3/8 inch in diameter, was inserted 5 feet from the base, into a hole 4-inches deep and 3/8 inch in diameter.

6. A *lead slug*, .30 caliber, copper jacketed, was inserted 6 feet from the base, into a hole 4-inches deep and 1/4 inch in diameter.

7. A *ceramic spike* (fig. 4), retrieved from a law enforcement case on the Siuslaw National Forest, Oreg., was inserted 6-1/2 feet from the base, into a hole 9-inches deep and 1 inch in diameter. This hole was not backfilled.

8. A *sixteen-penny nail* was driven into each log 7 feet from the base.

After placement, the location of each object was marked with paint on the log surface (fig. 5).

Figure 4. Ceramic spike used in tests.

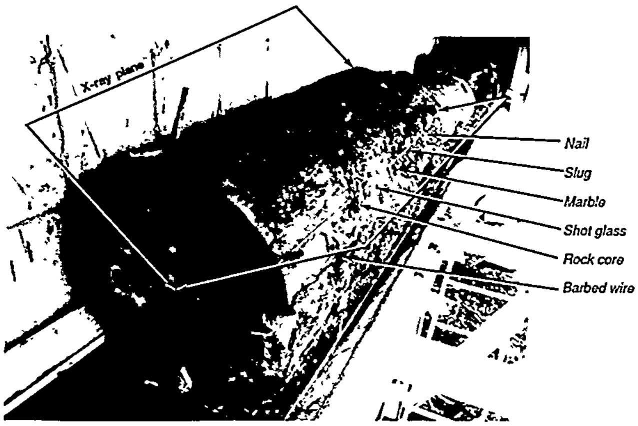


Figure 5. Test log No. 4.

TEST DESCRIPTION

A scanner containing three X-ray sources, each capable of up to 420 kilowatts (kW) of power was utilized to examine the test logs. Each source was aligned on the radial axis of the test log, equally spaced at 120 degrees, and located on a 8.7-foot radius circle (fig. 6). With each X-ray source creating an image, three views of each log are observed immediately after the run on a black-and-white monitor (fig. 7). With the conveyor moving a log at 120 feet per minute through the scanner, data were recorded every 0.1575 inch.

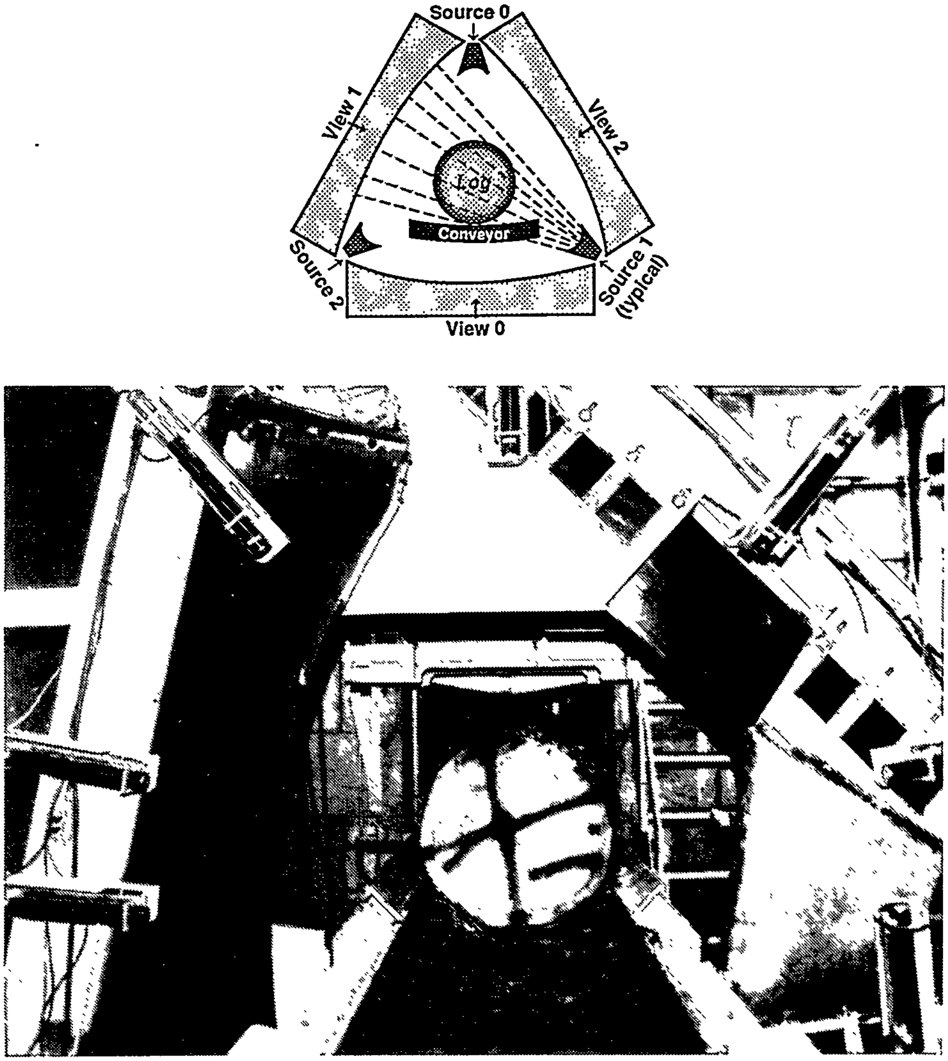


Figure 6. Scanner uses three X-ray sources to provide three views.

Figure 7. Computer monitor displays three views of log.

The variables considered when planning the test procedure were as follows:

1. Conveyor speed
2. X-ray power
3. Presence or absence of foreign objects
4. X-ray penetration
5. Distance of a foreign object to X-ray source
6. Species (density) influence.

All four test logs were placed on the conveyor belt that transported them through the scanner.

TEST RESULTS

Sufficient contrast for visual identification between the rock core and the log existed in at least two views of every log. Therefore, each test run was considered successful. However, some objects were seldom identified by a human operator, even though the images were computer enhanced. The human eye can detect about 65 shades of gray, whereas the electronic imaging system used in this test can recognize 265 shades.

The algorithm, developed by MacMillan Bloedel Research Ltd., in this system was designed to locate knots. The characteristics of the tested foreign objects and knots are sufficiently different that the software could not automatically search and recognize the objects. Test engineers made decisions based on viewing the monitor.

Table 1 describes a series of photographs of the monitor, organized to provide a brief overview of

Image No.	Log No.	View No.	Conveyor Speed (ft/min)	Power Level (kW)	Comments
I	1	0	120	420	No foreign objects
II	1	0	120	420	With foreign objects
III	1	0	60	420	Lower conveyor speed
IV	1	0	60	350	Lower power
V	1	0	60	420	Log rotated 90°
VI	2	0	60	420	Less dense log w/4X moisture
VII	3	0	60	420	Less dense log w/2X moisture
VIII	4	0	60	420	Larger dia log w/44% >moisture

Table 1. Test parameters were varied to determine how they affect the ability to detect foreign objects on the monitor. (See Appendix A for photographs of the monitor display)

how varying a parameter (conveyor speed, X-ray power, etc.) affects the ability to detect foreign objects. (See Appendix A) It should be noted that all the images were computer enhanced. The first image was made of log No. 1 traveling at 120 feet per minute and scanned at the 420 kW power setting. Most of the objects could be seen in one or more of the views. However, the wire inserted along the major axis of the log could not be seen in any of the views. Log No. 1 was selected as the reference and is used as the basis for comparison. Table 2 summarizes the objects that were visible on the monitor photographs.

Log No.	Barbed Wire No.1	Barbed Wire No.2	Rock	Glass	Marble	Slug	Spike	Nail
1			X	X	X	X	X	X
2		X	X	X	X	X	X	X
3		X	X	X		X	X	X
4			X	X		X	X	X

Table 2. Summary of objects seen in monitor display photographs.

Table 3 describes a series of views (with enhancement) replicated with the laser printer.(See Appendix B) These were selected for comparison with the photographs taken of the monitor (table 1). In most cases, view 0 has been selected because the objects are farthest from the source and most difficult to detect. Table 4 summarizes the objects that were visible on the laser jet prints.

Print No.	Log No.	View No.	Conveyor Speed (ft/min)	Power Level (kW)	Comments
I	1	0	120	420	No foreign objects
II	1	0	120	420	With foreign objects
III	1	0	60	420	Lower conveyor speed
IV	1	0	120	350	Lower power
V	1	0	60	420	Log rotated 90°
VI	2	0	60	420	Less dense log w/4X moisture
VII	3	0	60	420	Less dense log w/2X moisture
VIII	4	1	60	420	Larger dia log w/44% >moisture
IX	4	0	60	420	Differnet view

Table 3. Test parameters were varied to determine how they affect the ability to detect foreign objects on the laser jet prints. (See Appendix B for copies of the prints)

Log No.	Barbed Wire No.1	No.2	Rock	Glass	Marble	Slug	Spike	Nail
1			X	X		X		X
2			X	X	X	X	X	X
3		X	X	X		X	X	X
4			X			X	X	X

Table 4. Summary of objects seen in laser jet prints.

The knot-detection software program generated graphics showing oblique and end views of the logs with locations of the detected objects shown by arrows (See Appendix C). This is one example of the type of output from a scanning system. Table 5 summarizes the objects that were detected by the electronic imaging system.

Log No.	Barbed Wire No.1	No.2	Rock	Glass	Marble	Slug	Spike	Nail
1	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X
4			X	X			X	X

Table 5. Summary of objects detected by electronic imaging system.

CONCLUSIONS

An X-ray scanner of the type employed in this test is sufficiently powerful to provide visual detection of foreign objects in logs. The three-source configuration is quite satisfactory.

A custom imaging software program containing algorithms for the recognition of foreign objects in logs can be developed for the X-ray system employed. Automated object detection and subsequent decision making would be faster and possibly more accurate than that of a human observer using a monitor. This is because the gray scale resolution using a computer is far superior to human ability. Based on the results of these tests, there is a good chance that such a program, used in conjunction with an X-ray scanner, will solve the problem of foreign objects in logs at the mill site.

APPENDIX A—*Monitor displays showing X-ray images of logs.*

LEGEND	
1 & 2	Barbed Wire
3	Rock Core
4	Shot Glass
5	Glass Marble
6	Lead Slug
7	Ceramic Spike
8	Nail

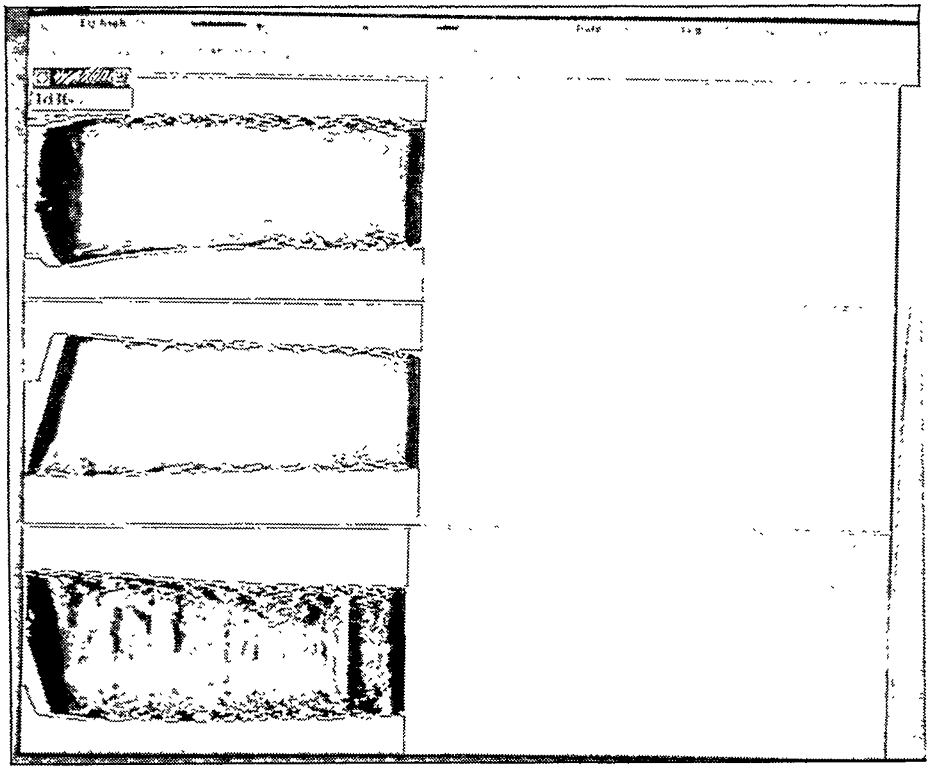


Image No I. Three views of 36 inch diameter Douglas Fir log before inserting foreign objects.

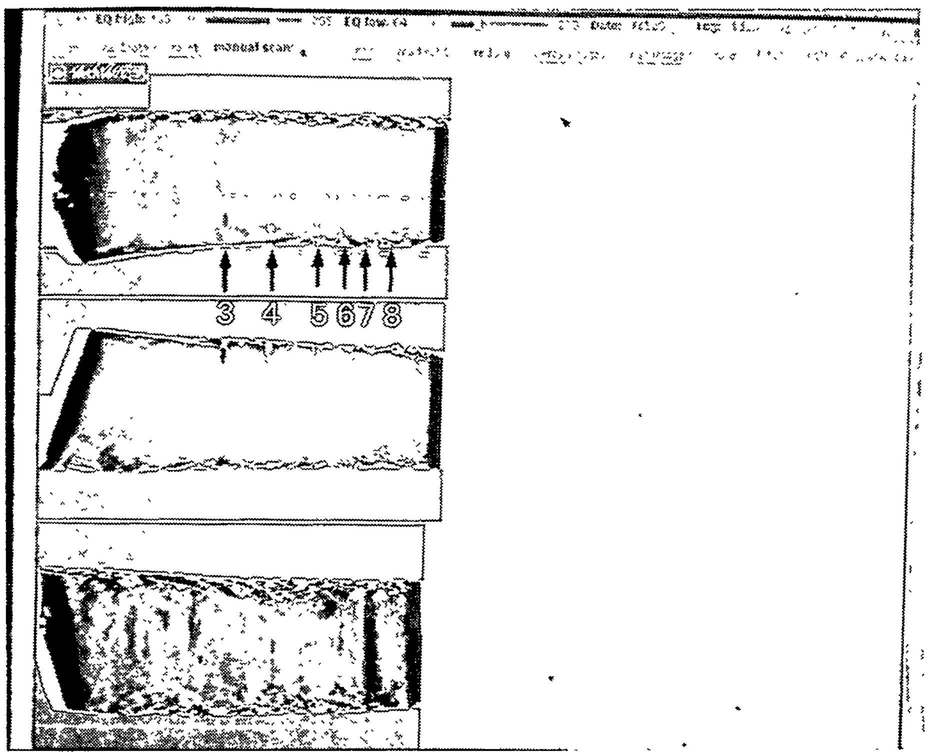


Image No II. The same log with the objects in place.

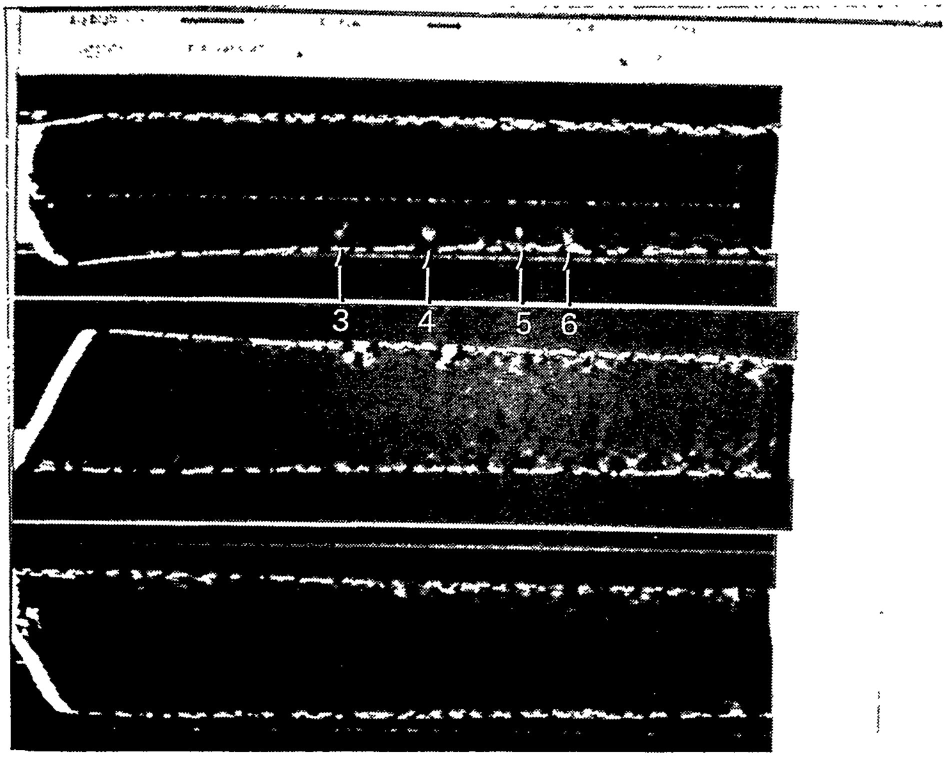


Image No III. Same log with conveyor traveling slower (60 fpm).

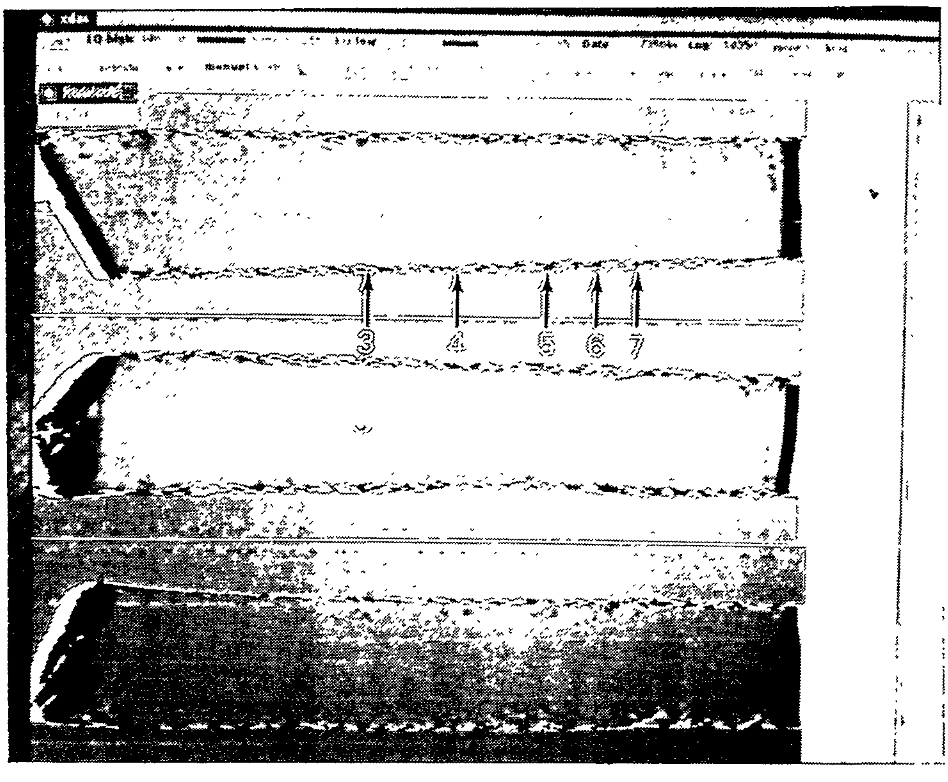


Image No IV. Same log with reduced power (350kW).

LEGEND	
1 & 2	Barbed Wire
3	Rock Core
4	Shot Glass
5	Glass Marble
6	Lead Slug
7	Ceramic Spike
8	Nail

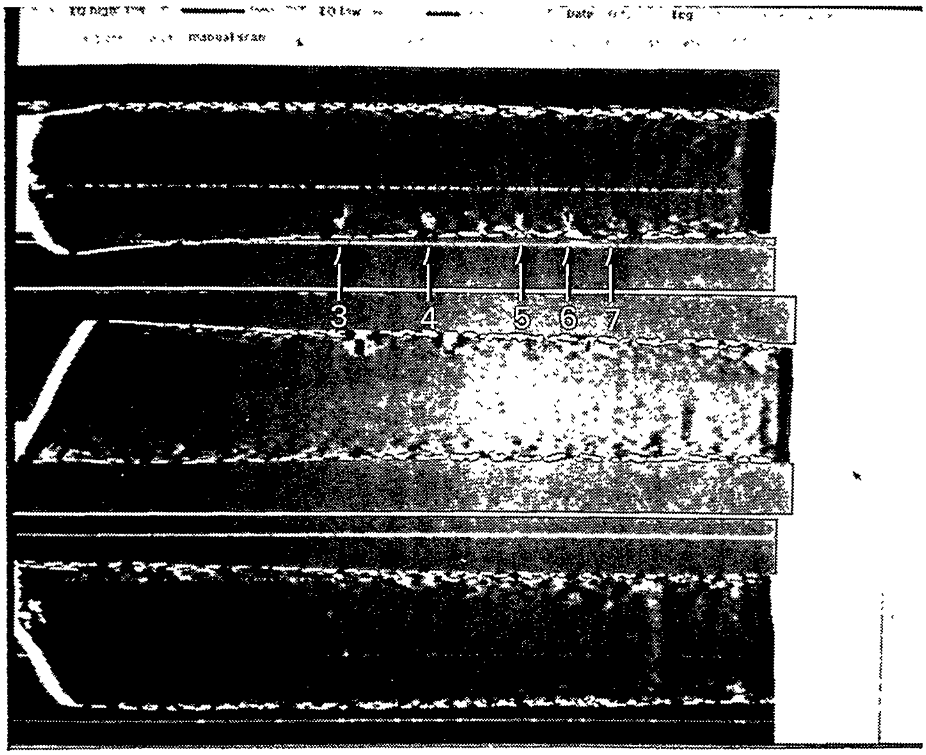


Image No V. Same log rotated 90 degrees on the conveyor belt.

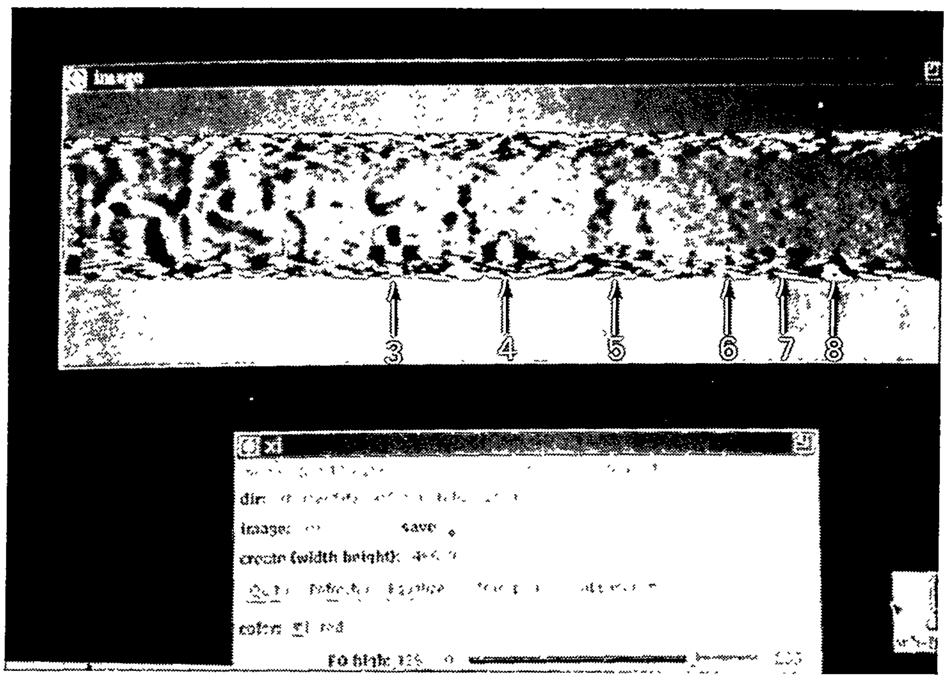
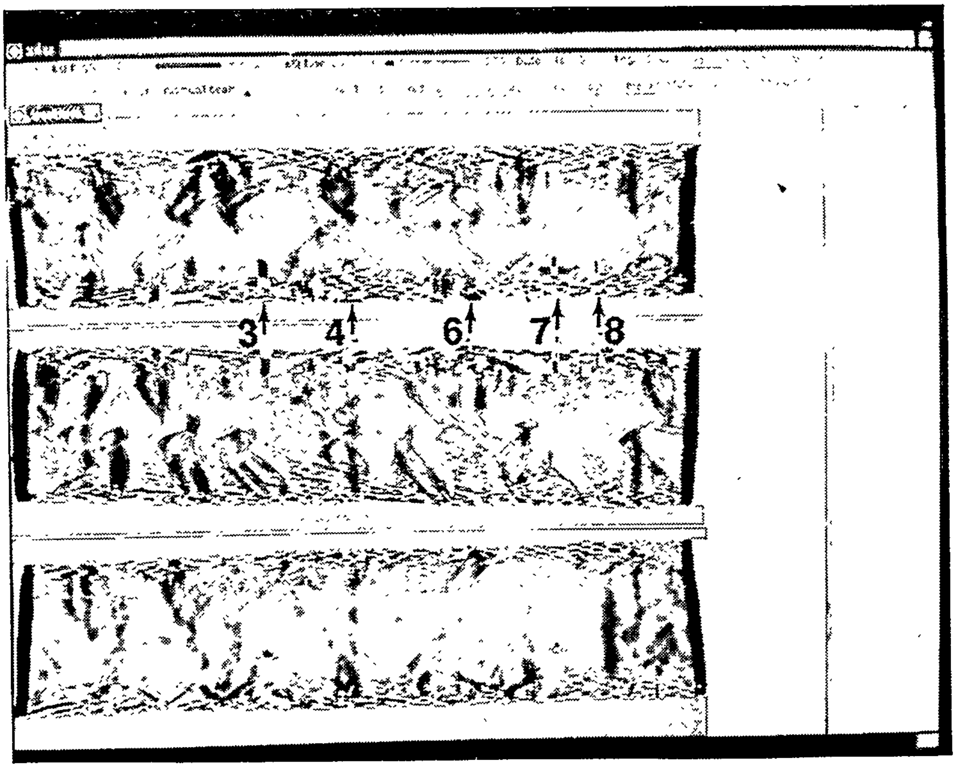
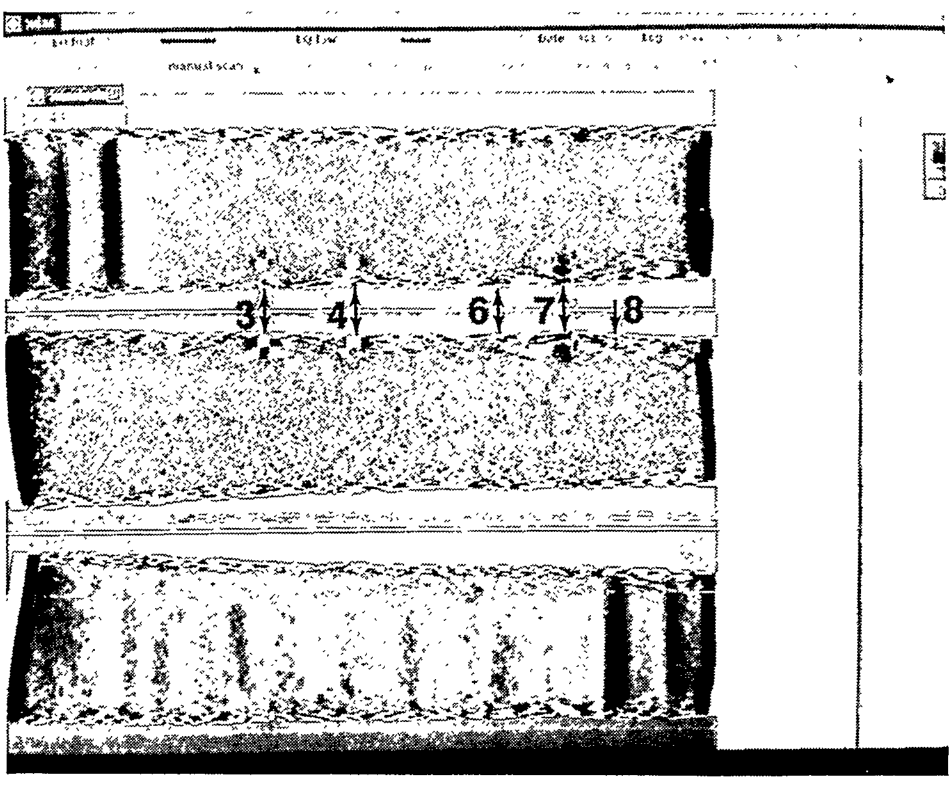


Image No VI. One view of the Hemlock log with objects, scanned at 420kV, moving at 60 fpm conveyor speed.



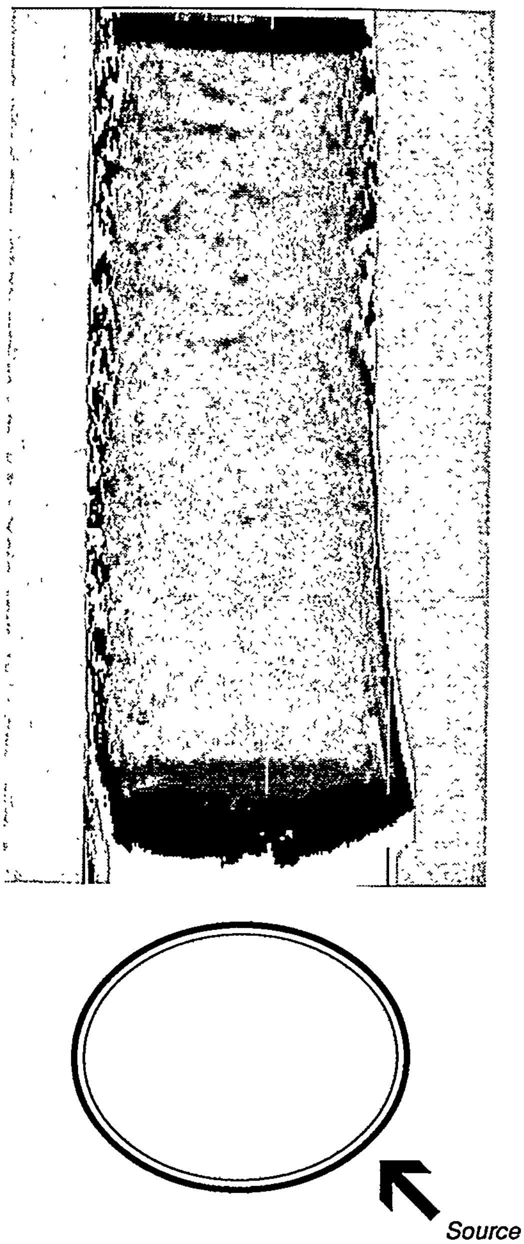
LEGEND	
1 & 2	Barbed Wire
3	Rock Core
4	Shot Glass
5	Glass Marble
6	Lead Slug
7	Ceramic Spike
8	Nail

Image No VII. A 42 inch diameter Cedar log (No. 3) that is bigger but less dense than either log above and is being scanned under conditions similar to the Hemlock log above.

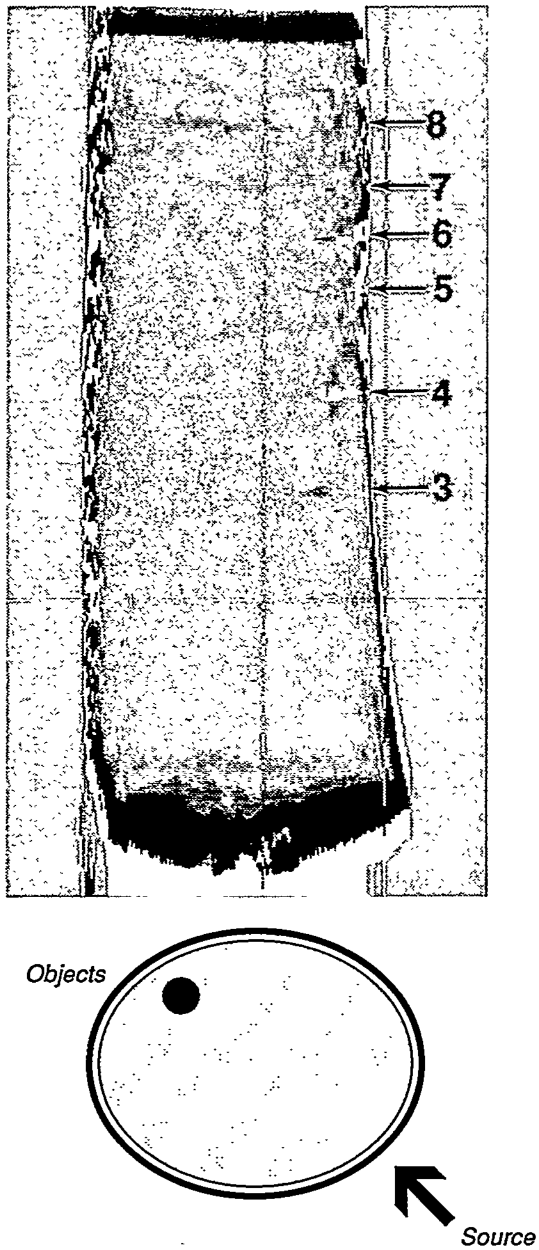


VIII. A large Douglas Fir log (log roll) traveling through the scanner under conditions identical to the Cedar and Hemlock logs above.

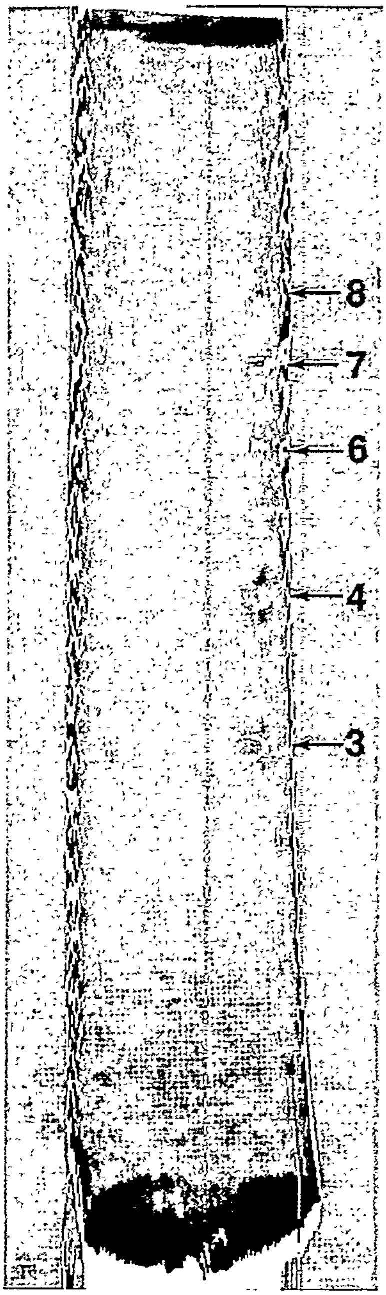
APPENDIX B—*Prints from laser printer showing X-ray images of logs.(Referenced in Table 3)*



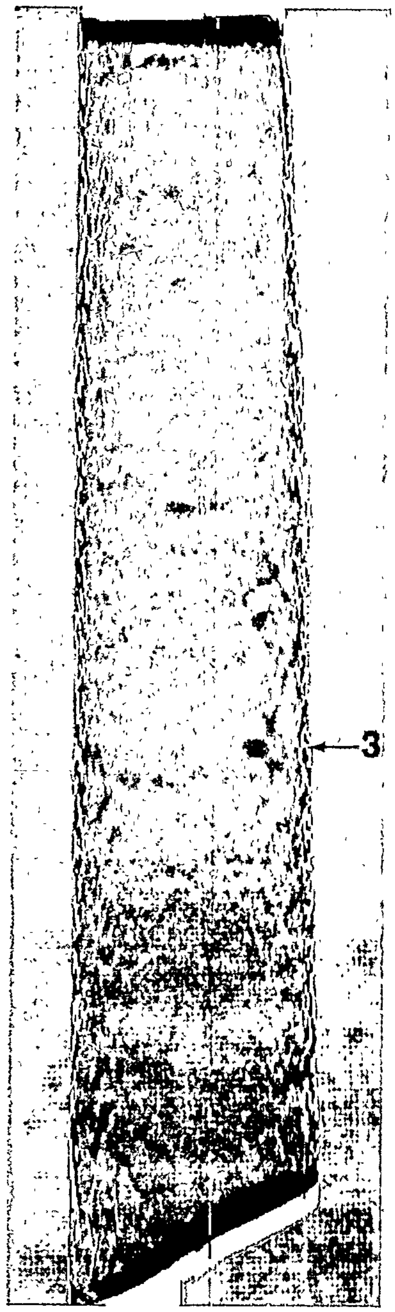
Print No I. View 0 of Log No 1 (36" diameter Douglas Fir) before inserting foreign objects.

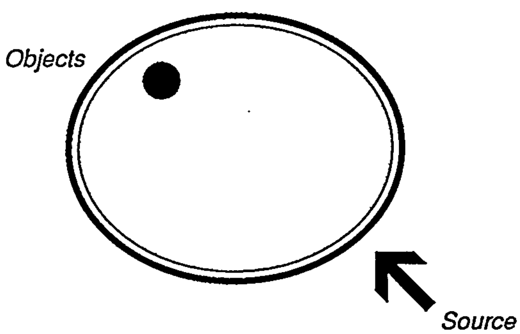


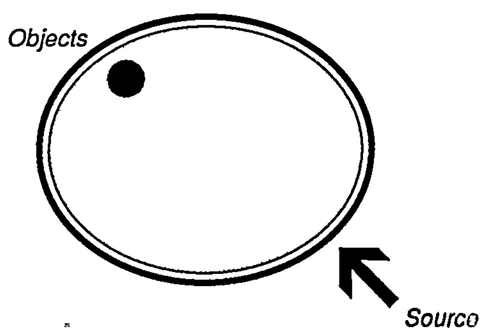
Print No II. The same log with the objects in place.



LEGEND	
1 & 2	Barbed Wire
3	Rock Core
4	Shot Glass
5	Glass Marble
6	Lead Slug
7	Ceramic Spike
8	Nail

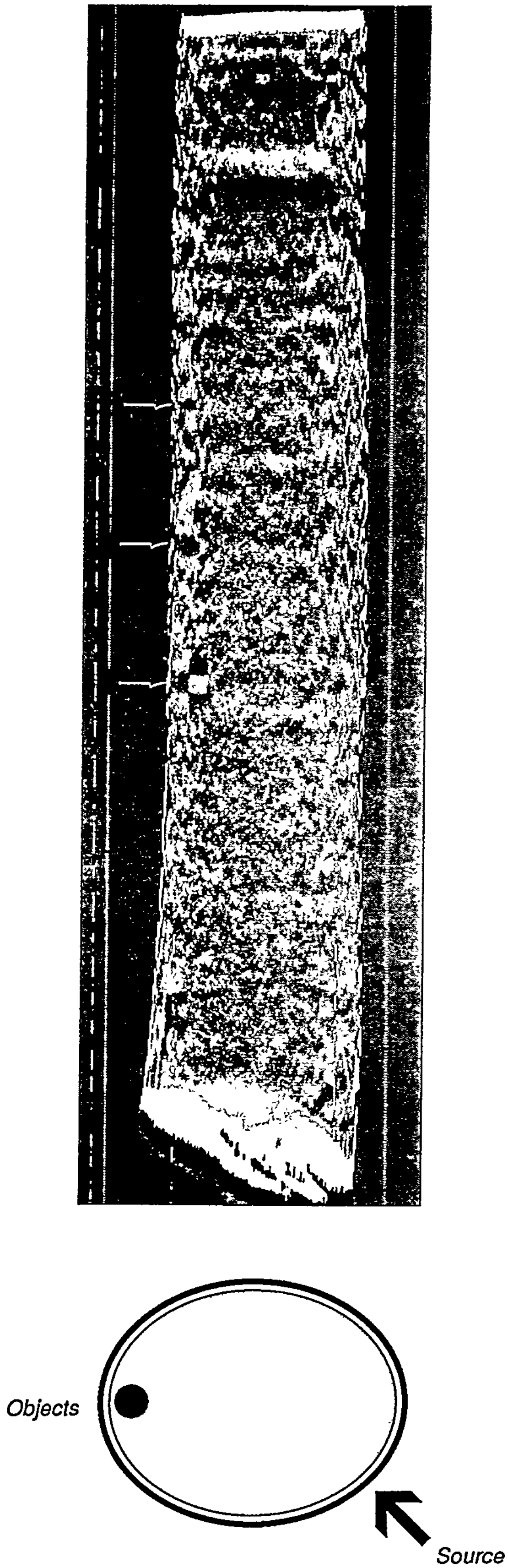


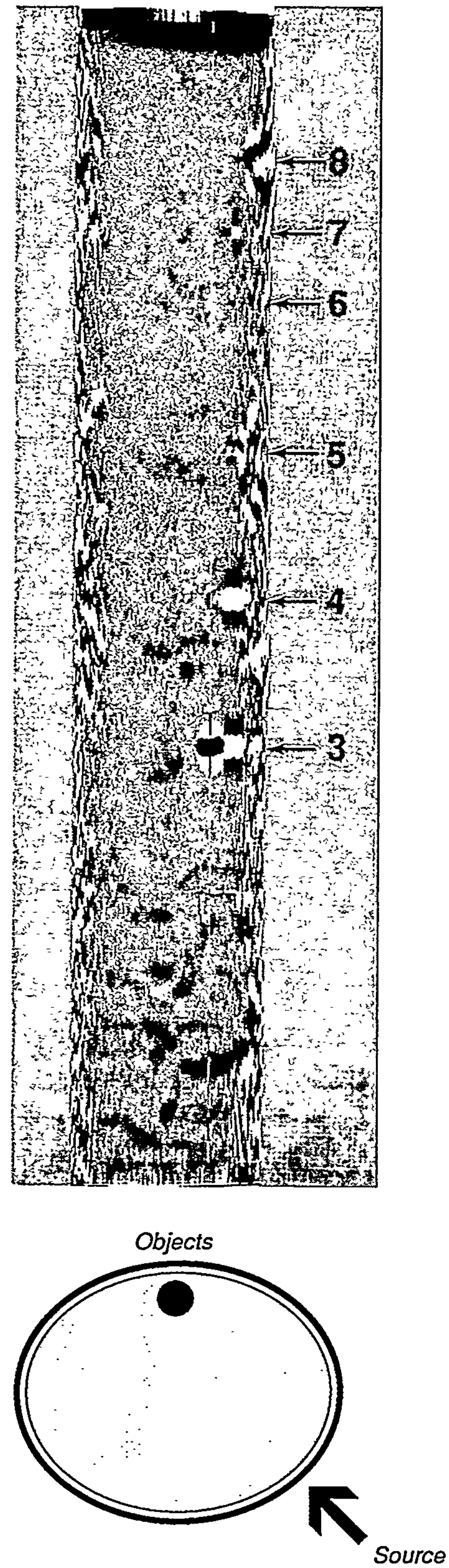




Print No III. Same log at lower conveyor speed.

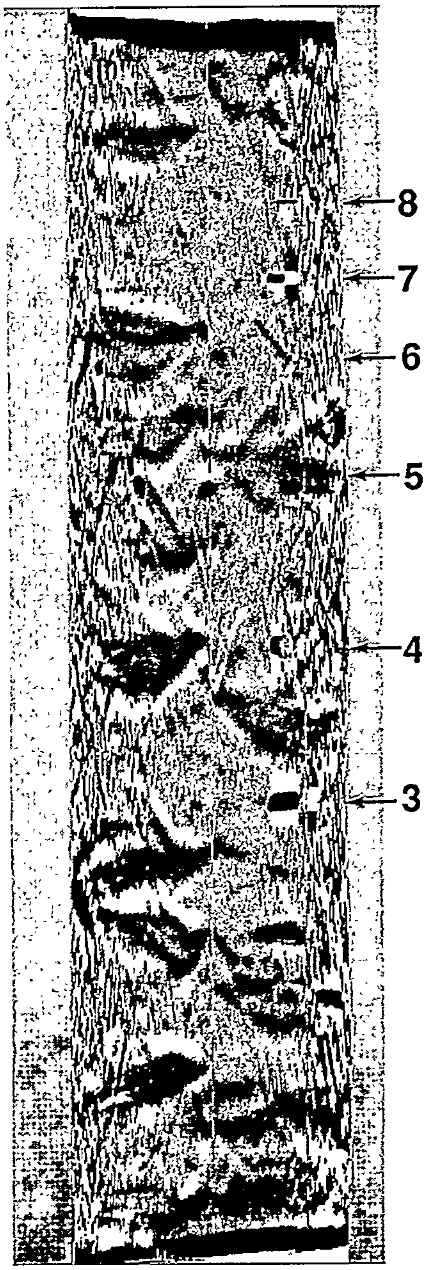
Print No IV. Same log with reduced power.





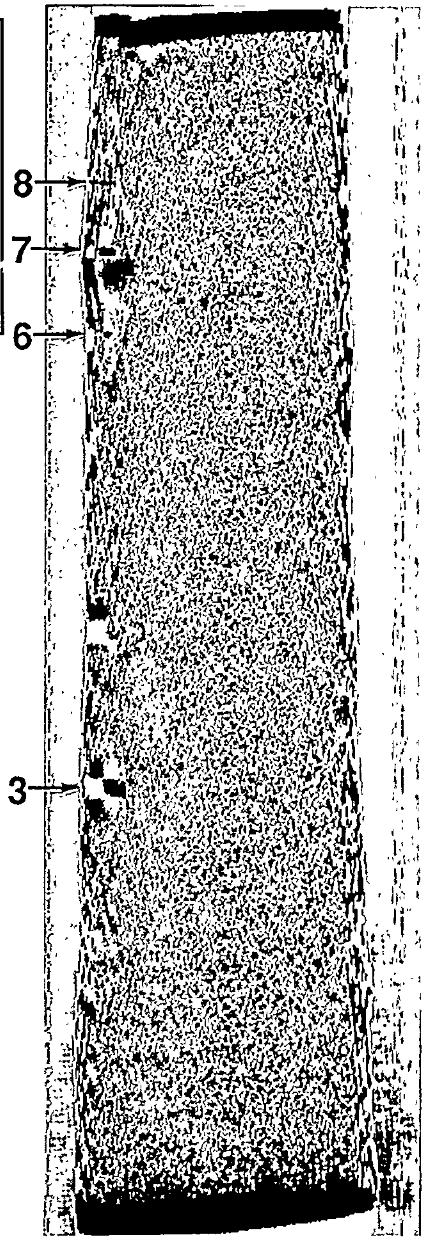
Print No V. Log #1 (same as Print No. III) except log has been rotated 90°.

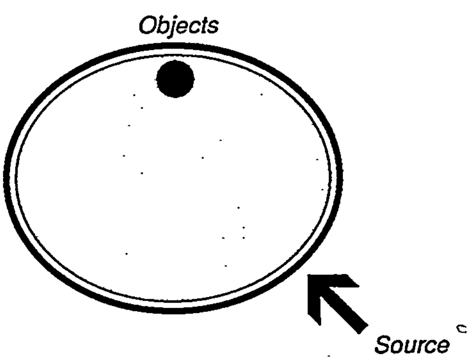
Print No VI. Log #2 was less dense than Log #1 and had 4 times the moisture.



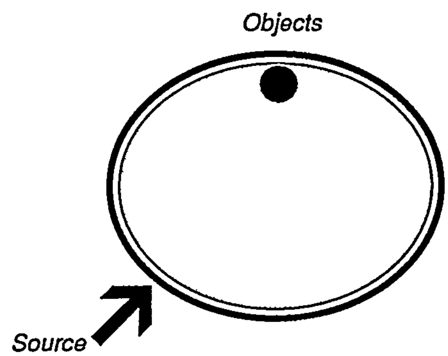
LEGEND

1 & 2	Barbed Wire
3	Rock Core
4	Shot Glass
5	Glass Marble
6	Lead Slug
7	Ceramic Spike
8	Nail

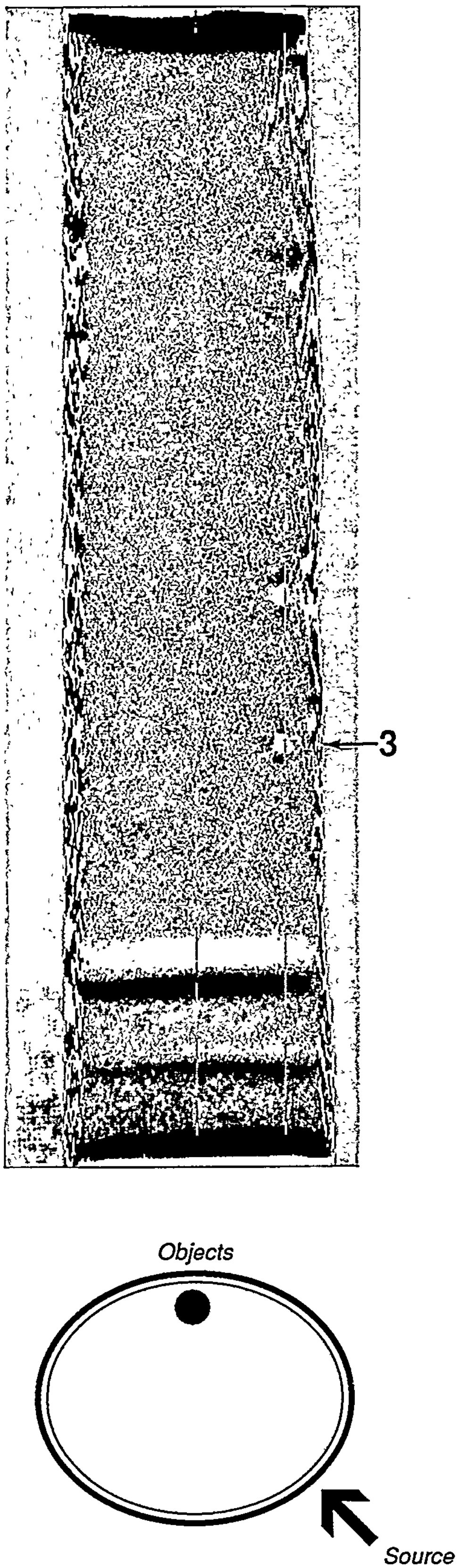




Print No VII. Log #3 had lower density than log #1 and 2 times as much moisture.

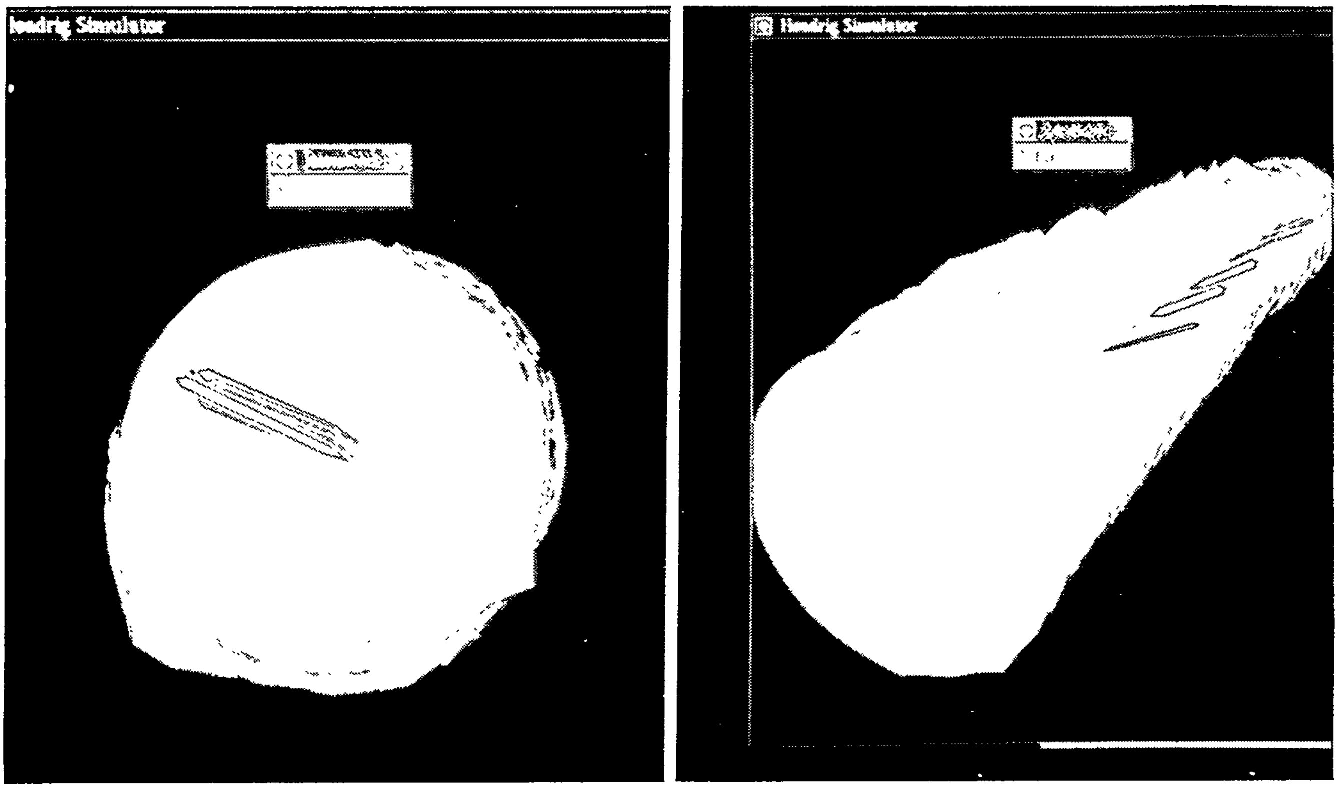


Print No VIII. Log #4 has larger diameter and 44% more moisture than log #1.



Print No IX. Log #4 shown from a different view.

APPENDIX C—*Graphic output from electronic imaging system.*



I. Graphic output from electronic imaging system shows object locations in log #1.