Contract No:

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WESTINGHOUSE SAVANNAH RIVER COMPANY

INTER-OFFICE MEMORANDUM

SRT-MTS-93-3119

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November 29, 1993

To: A. G. Eggers

From: D. R. Leader

Packing Material Compression Tests (U)

Summary:
Two inch cubes of cane fiberboard and three different types of ceramic fiberboard were compressed in the Materials Lab testing machine to determine their energy absorption characteristics. Some 2-inch cube samples of each material were compressed by a 2-inch square punch while the sample was constrained on five sides by a die, and one sample of each type was compacted by the punch with no restraint on the sides. The major difference between the materials is that the cane fiberboard did not break up during any test, while all of the ceramic fiberboard samples broke up into both large pieces and fine powder during compaction. There are also differences in the deflection rate for the various materials. A plot of load vs deflection was made during each compression test and these curves are attached to this memo.

Background:

Shipping packages for off site shipment of radioactive material are made from commercial open top drums. Typically, each drum is completely filled with disks of cane fiberboard, with a cylindrical cavity in the center that is large enough to hold the containment vessels that contain the radioactive material. The fiberboard is intended to absorb energy and protect the primary container from damage during an accident. Each shipping container is designed to survive a series of hypothetical accident conditions that include a series of drops onto an unyielding surface and then a fire.

When the loaded shipping container is dropped, the drum is deformed, causing the contained cane fiberboard to be compressed and absorb some of the energy that otherwise could result in deformation of the enclosed containment vessel.

The fire that follows the drop in the hypothetical accident test series could result in burning of the cane fiberboard near the vent holes in the steel drum. Replacement of cane fiberboard in these areas with a rigid ceramic based non combustible board with mechanical properties similar to that of cane fiberboard is being considered.

In addition to finding a non combustible material to replace some cane fiberboard in the shipping package, there is a desire to develop a finite element model of the shipping package to demonstrate or corroborate the drop test results. The stress deflection curves for the packing material inside of the drum is needed for this analysis.

Discussion:
A series of compression tests was done in the Materials Laboratory to develop quantitative data on the behavior of cane fiberboard and other candidate materials during compression.

The materials tested were cane fiberboard, Kaowool-S®, Kaowool-M® and Ceraboard-85®. The cane fiberboard is manufactured as 1/2-inch thick boards and made into 2-inch thick board by gluing four pieces together with carpenters wood glue. The Ceraboard-85® is manufactured 1-inch thick and two pieces were glued together with the same glue to form a 2-inch thick sample. The other materials were manufactured 2-inches thick.

Because the packing material in the shipping container is constrained by the drum during actual conditions, it was decided to constrain the sample materials in a die during some of the compaction tests. A rectangular steel die with a cavity having a square 2" x 2" cross section and a depth of four inches was fabricated for this series of tests. A 1/2-inch thick plate two inches square was first placed in the bottom of the die cavity, followed by a 2-inch cube of one of the materials being tested. A 2-inch square punch was then placed on top of the sample and the assembly was placed in the Materials Laboratory 400,000 pound capacity testing machine. The sample was preloaded to verify contact between the machine and the test sample, and then the load was increased by driving the punch down into the die at a rate of 2 1/4-inches per minute. During each compaction test, load was plotted as a function of punch position. Each test was terminated when the load reached approximately 70,000 pounds.

The "preload" value is noted in the top margin of each chart. This is the load that was on the sample at the time the test was started with the pen at the origin of the chart. In most cases the preload was 20 pounds but it was as high as 160 pounds for one test.

The thickness of each sample was measured after it was removed from the die. An attempt was made to run tests on each material with the axial load in different orientations to the "grain" of the material. This was no problem for the cane fiberboard which has long fibers that are laying parallel to the one surface, but it was difficult to determine the orientation of the fibers in the ceramic boards. In addition to the compression tests where the samples were compressed in the die, one sample of each material was compacted with the punch placed directly on top of the unconstrained 2-inch cube of the sample material. The charts from all of these tests are attached to this memo.

There was no lubricant used between the sample and the walls of the die, and there is a small gap between the side of the punch and the wall of the die. During all of the tests except those where the cane fiberboard was compacted with the fibers parallel to the punch face, some of the test material extruded into the space between the punch and/or the bottom plate and the die. Some of the load required to compact these samples was caused by friction between the sample material and the wall of the die. This factor should be considered during analysis of the data.

A major difference between the cane fiberboard now in use in shipping containers and the ceramic fiberboard samples is that the long fibers in the cane fiberboard hold the material together during the deformation process, while the ceramic materials are more brittle and tend to crumble into fine dust. Although airborne ceramic dust may not be a major concern in shipping package design it is a characteristic of all of the ceramic test samples that should be recognized. The cane fiberboard sample that was tested without being constrained by the die remained in one piece and was simply compressed with no major bulging on the sides. All of the ceramic fiberboard samples shed large pieces shortly after the start of deformation and small pieces and powder continued to be shed during the entire compaction process. Only about 60% of the original ceramic material remained under the punch at the conclusion of the compaction test, and this piece was very brittle and fragile.

There are nineteen load-deflection curves and one calibration chart attached to this report. All of the charts have been reproduced at 78% of their original size. The calibration chart relates punch deflection in inches to chart position, and load in pounds to chart position. The calibration chart was generated by incrementally loading or moving the machine and recording load or position. Following is a listing of the test charts by test or chart number along with a brief summary of the information on each chart:

1. **Cane fiberboard** compacted in the die with the fibers of the fiberboard parallel to the face of the punch.
Preload: 20 pounds
Final load: 79,630 pounds
Final thickness of sample: 0.445"
No "flash" in punch-die gap.
Note: On this first test the machine loading was stopped momentarily at 41,600 pounds and then increased to 79,630 pounds. The break in the curve resulted from this hesitation.

2. **Cane fiberboard.** This test is a repeat of the first test conditions.
Preload: 20 pounds
Final load: 67,010 pounds
Final thickness of sample: 0.426"
No "flash" in punch-die gap.

3. **Cane fiberboard.** This test is a repeat of the first test conditions.
Preload: 20 pounds
Final load: 70,140 pounds
Final thickness of sample: 0.432"
No "flash" in punch-die gap.

4. **Cane fiberboard** This is a repeat of the first test conditions except that the plane of the fibers in the fiberboard was oriented perpendicular to the punch face.
Preload: 20 pounds
Final load: 74,760 pounds
Final thickness of sample: 0.365"
Because the fibers were oriented in a plane perpendicular to the punch face, some fibers moved into the gap between the punch and the die wall. The average thickness of this "flash" was about .075" and it extended about 3/4-inch up and 1/2-inch down.

5. **Cane fiberboard.** Repeat of test 4.
Preload: 110 pounds
Final load: 69,020 pounds
Final thickness of sample: 0.390"
"Flash" in the gap both above and below the sample.

6. **Cane fiberboard.** Repeat of test 4.
Preload: 20 pounds
Final load: 70,660 pounds
Final thickness: 0.385"
"Flash" in the gap both above and below the sample.

7. **Kaowool S** • sample compacted in the die. One surface of the sample had a "wrinkled" appearance, and this surface was placed against the face of the punch in the die.
Preload: 20 pounds
Final load: 74,980 pounds
Final thickness: 0.355"
"Flash" in the gap both above and below the sample. Broken pieces of the flash were .075" thick.
After compaction, the sample was very brittle and powdery. The edges and corners were rounded and powder would come off if touched or rubbed.

8. **Kaowool S ®**. Repeat of test 7 except that the "wrinkled" surface of the sample was in contact with the die wall rather than the punch face.
Preload: 160 pounds
Final load: 70,980 pounds
Final thickness: 0.373"

"Flash" in the gap both above and below the sample, but it all broke up into powder before it could be measured.

After compaction, the sample was very brittle and powdery. The edges and corners were rounded and powder would come off if touched or rubbed.

9. **Kaowool S ®**. Repeat of test 7.

Preload: 20 pounds
Final load: 72,350 pounds
Final thickness: 0.373"

"Flash" in the gap both above and below the sample, but it all broke up into powder before it could be measured.

After compaction, the sample was very brittle and powdery. The edges and corners were rounded and powder would come off if touched or rubbed.

10. **Cane fiberboard**. Large sample of cane fiberboard, 2-inches thick with the punch pressing down in the center of the sample perpendicular to the surface of the sheet. The die was not used.

Preload: 20 pounds
Final load: 69,970 pounds
Final thickness could not be measured because of the configuration of the deformed sample.

The punch made a rectangular depression in the sheet, and the material around the outside of the punch deflected upward. The fibers were not cut by the punch.

11 Kaowool M ® sample compacted in the die. The orientation of the fibers could not be determined, but one surface appeared to be particularly smooth, and this surface was oriented parallel to the punch face.

Preload: 80 pounds
Final load: 71,710 pounds
Final thickness: 0.441 inches

"Flash" in the gap both above and below the sample, but it all broke up into powder before it could be measured.

After compaction, the sample was very brittle and powdery. The edges and corners were rounded and powder would come off if touched or rubbed.

12. Kaowool M ® sample compacted in the die. This is a repeat of test 11, except that the smooth surface was oriented parallel to the die wall.

Preload 10 pounds
Final load: 69,220 pounds
Final thickness: 0.433 inches

"Flash" in the gap both above and below the sample, but it all broke up into powder before it could be measured.

After compaction, the sample was very brittle and powdery. The edges and corners were rounded and powder would come off if touched or rubbed.

13. Kaowool M ® sample compacted in the die. This is a repeat of test 11.

Preload: 20 pounds
Final load: 70,560 pounds
Final thickness: 0.431 inches

"Flash" in the gap both above and below the sample, but it all broke up into powder before it could be measured.

After compaction, the sample was very brittle and powdery. The edges and corners were rounded and powder would come off if touched or rubbed.

14. **Ceraboard 85** ® sample compacted in the die. The sample was made from two 1-inch thick samples glued together with carpenters wood glue. This test was done in the die with the punch face parallel to the surface of the Ceraboard 85®

Preload: 20 pounds
Final load: 77,360 pounds
Final thickness: 0.355 inches

"Flash" in the gap both above and below the sample, but it all broke up into powder before it could be measured.

Although all of the ceramic board samples were brittle, this material is more fragile, brittle and powdery than the others after compaction.

15. **Ceraboard 85** ® sample compacted in the die. This is a repeat of test 14 except that the surface of the sheet was in contact with the die wall.

Preload: 30 pounds
Final load: 80,840 pounds
Final thickness: 0.322 inches

"Flash" in the gap both above and below the sample, but it all broke up into powder before it could be measured.

This sample was even more fragile than the sample from test number 14.

16. **Ceraboard 85** ® 2 x 2 x 2 sample placed directly under the 2-inch square punch but with no die to offer restraint.

Preload: 20 pounds
Final Load: 73,390 pounds
Final thickness: 0.249 inches
Original sample weight: 40.4 grams
Weight of compacted sample under punch: 23.1 grams

During compaction, large sections of the sample from the unrestrained edges crumbled off of the sample. The final thickness of the material under the punch was smaller than that of samples compacted in the die, because there was less material to compact. The material that broke off was both in the form of large pieces and fine powder.

17. **Kaowool S ®** sample. This is a repeat of the test conditions in test 16 with the exception of the material.

Preload: 30 pounds
Final load: 76,560 pounds
Final thickness: 0.195 inches

During compaction, large sections of the sample from the unrestrained edges crumbled off of the sample. The final thickness of the material under the punch was smaller than that of samples compacted in the die, because there was less material to compact. The material that broke off was both in the form of large pieces and fine powder.

18. **Kaowool M ®** sample. This is a repeat of the test conditions in test 16 with the exception of the material.

Preload: 30 pounds
Final load: 74,000 pounds
Final thickness: 0.224 inches

During compaction, large sections of the sample from the unrestrained edges crumbled off of the sample. The final thickness of the material under the punch was smaller than that of samples compacted in the die, because there was less material to compact. The material that broke off was both in the form of large pieces and fine powder.

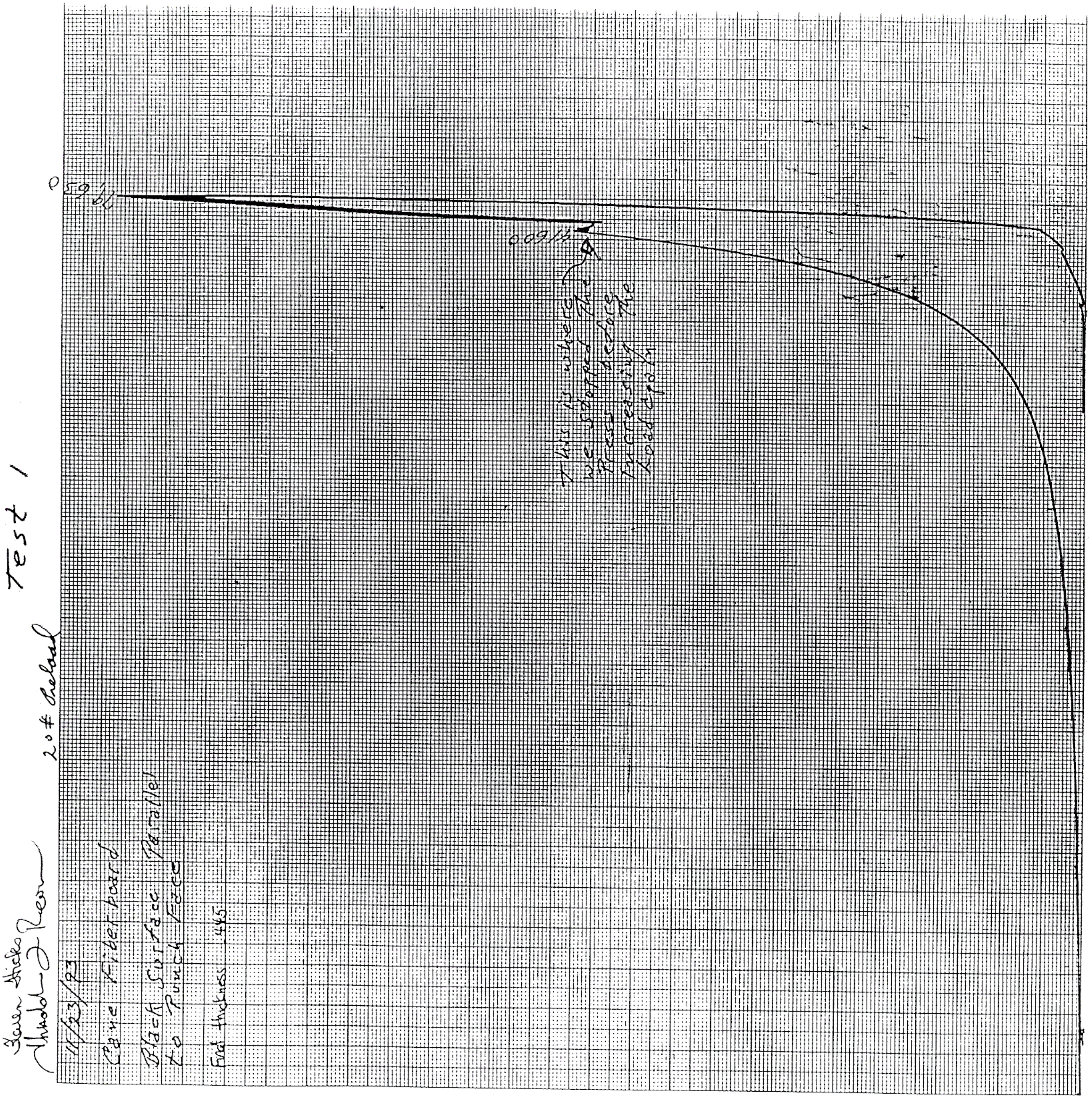
19. **Cane fiberboard.** This is a repeat of the test conditions in test 16, with the exception of the material. The punch face was parallel to the surface of the fiberboard.

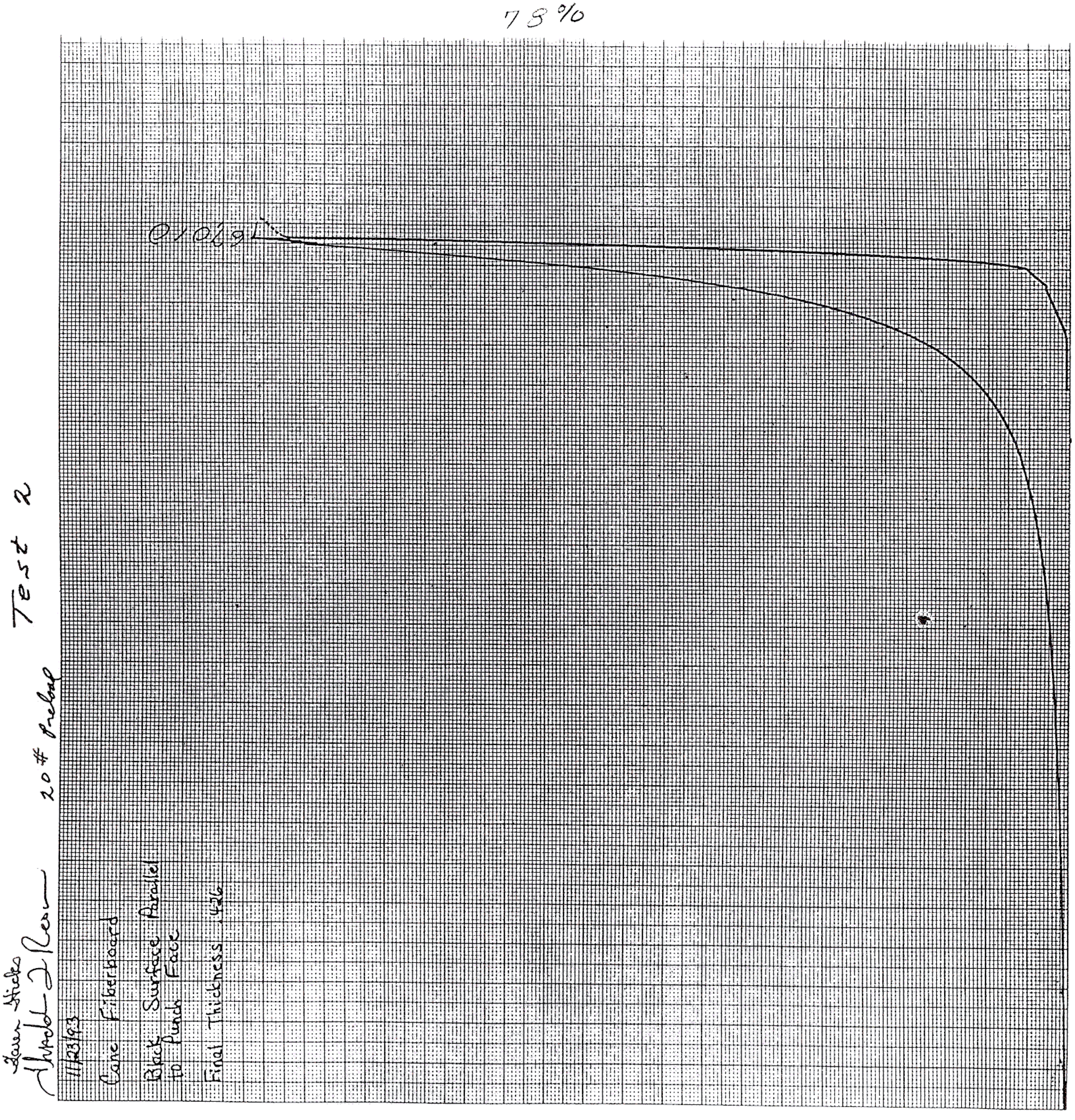
Preload: 20 pounds
Final load: 72,370 pounds
Final thickness: 0.414 inches

No material was lost during compaction, and there was only slight increase in the width of the sample.

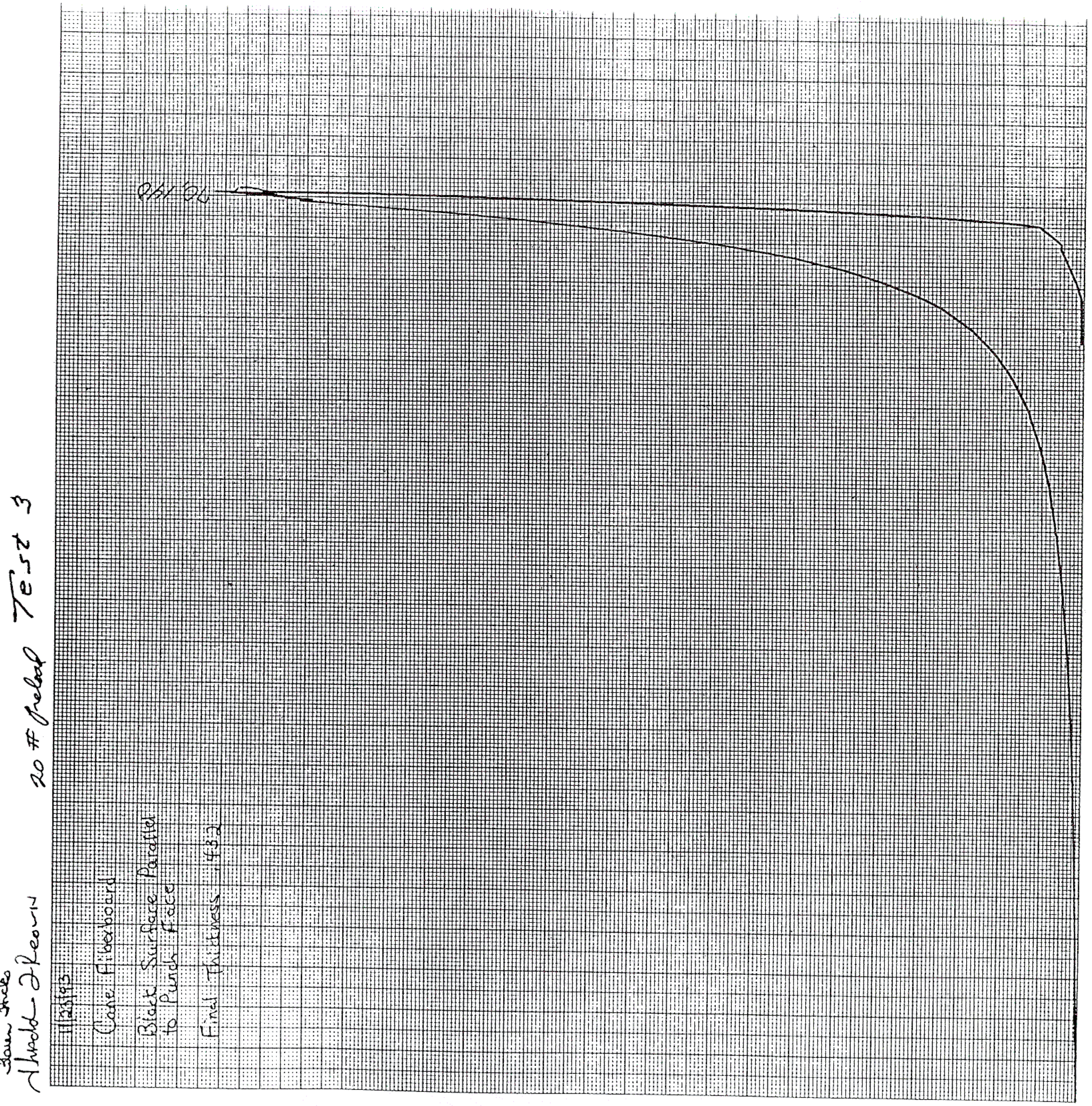
20. **Test Machine Calibration.** This calibration chart can be used in conjunction with the other figures to determine the load and punch position at any point on the curves.

78%


This is where we stopped the press before increasing the load again
Test 1
20# Preload
11/23/93
Cane Fiberboard
Black Surface Parallel to Punch Face
End thickness .445

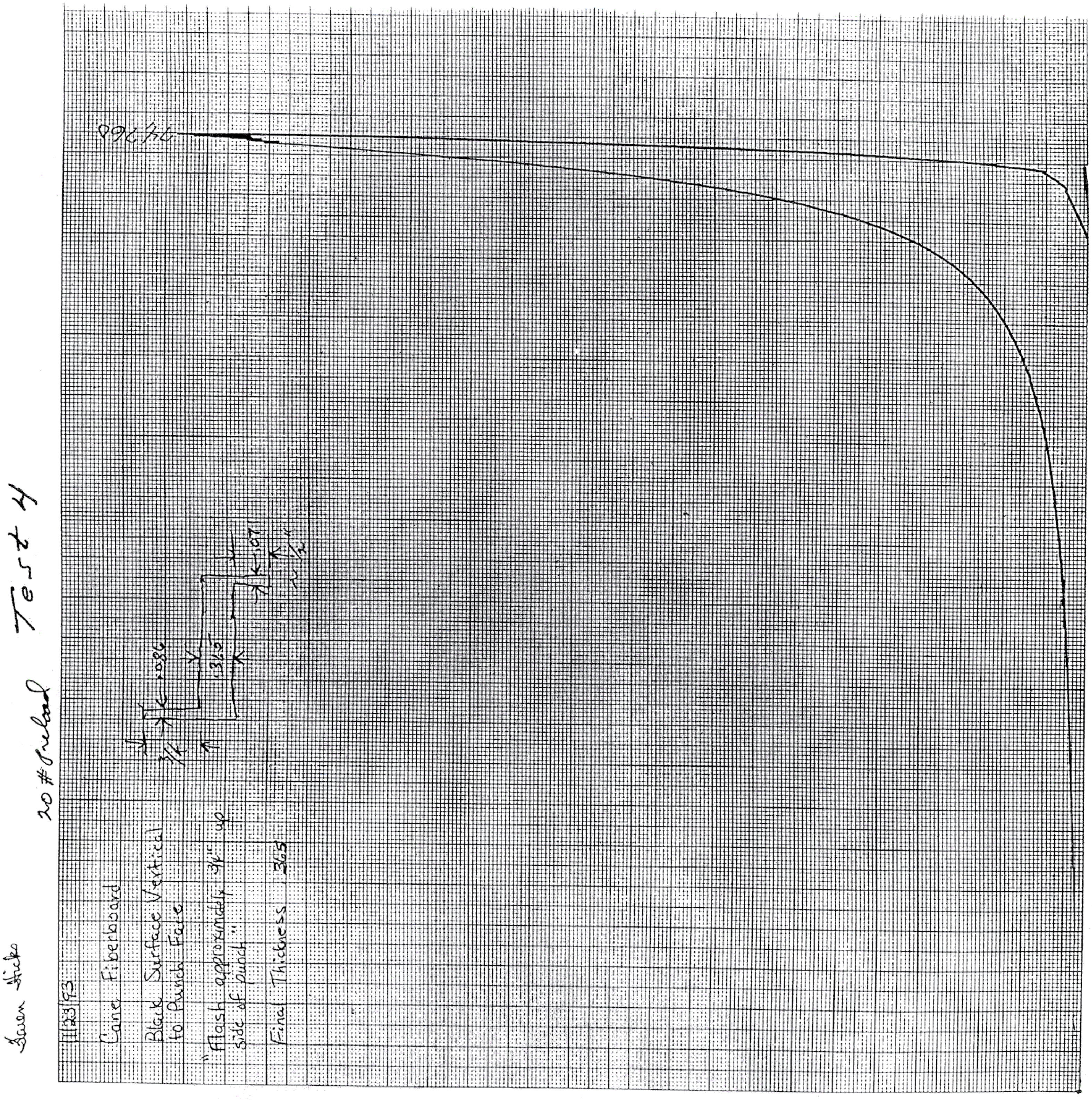

78%
0.0291
Test 2
20# Preload
11/23/93
Cane Fiberboard
Black Surface Parallel
to Punch Face
Final Thickness .426

78%

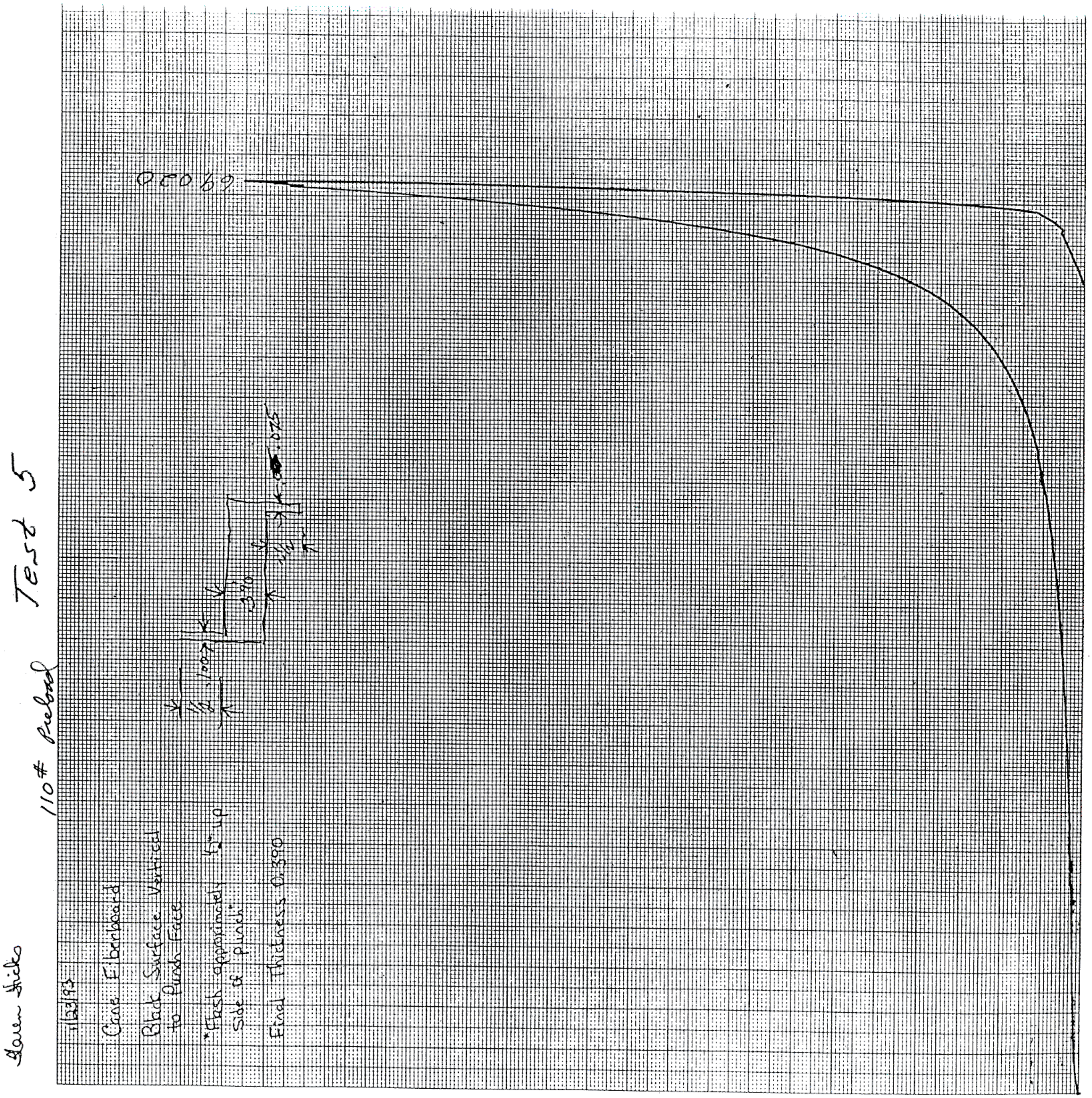


20 # preload Test 3
11/23/93
Cane Fiberboard
Black Surface Parallel to Punch Face
Final Thickness .432

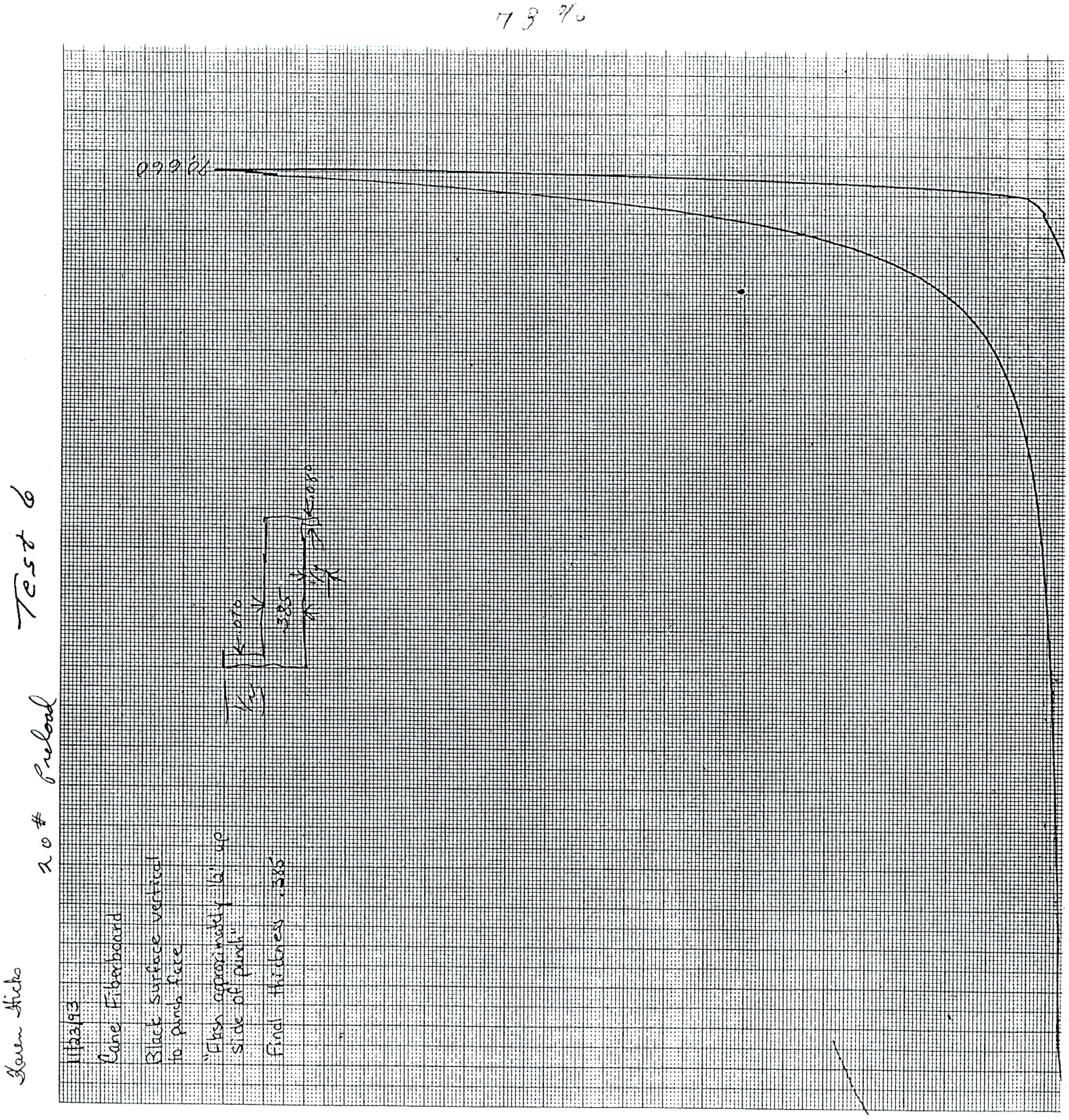
78 %


14766
11/23/93
Cane Fiberboard
Black Surface Vertical
to Punch Face
"Flash approximately 3/4" up
side of punch"
Final Thickness .365
3/4
.086
.365
.071
~1/2"
20 # Preload
Test 4
Karen Hicks
4

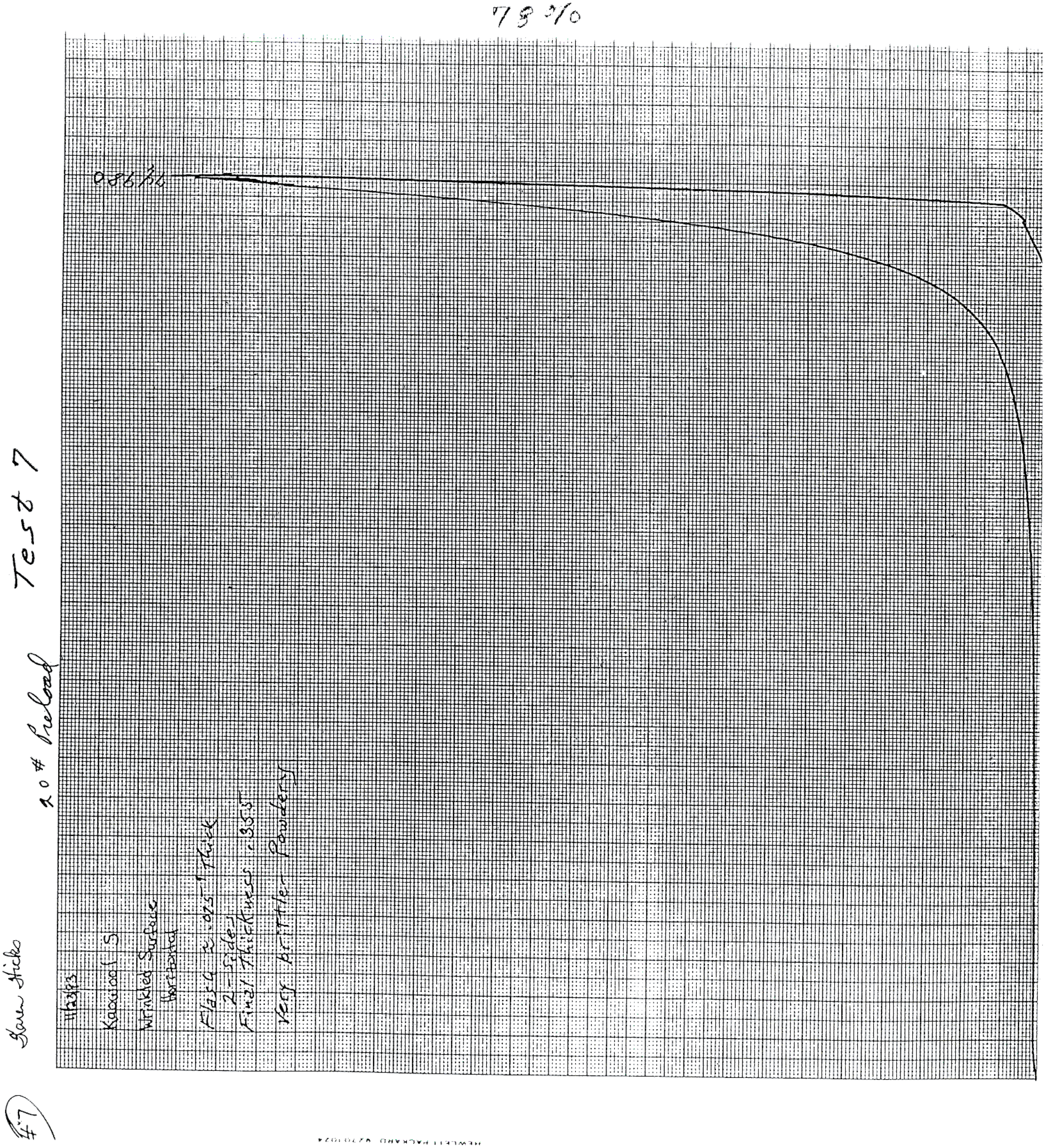
78%

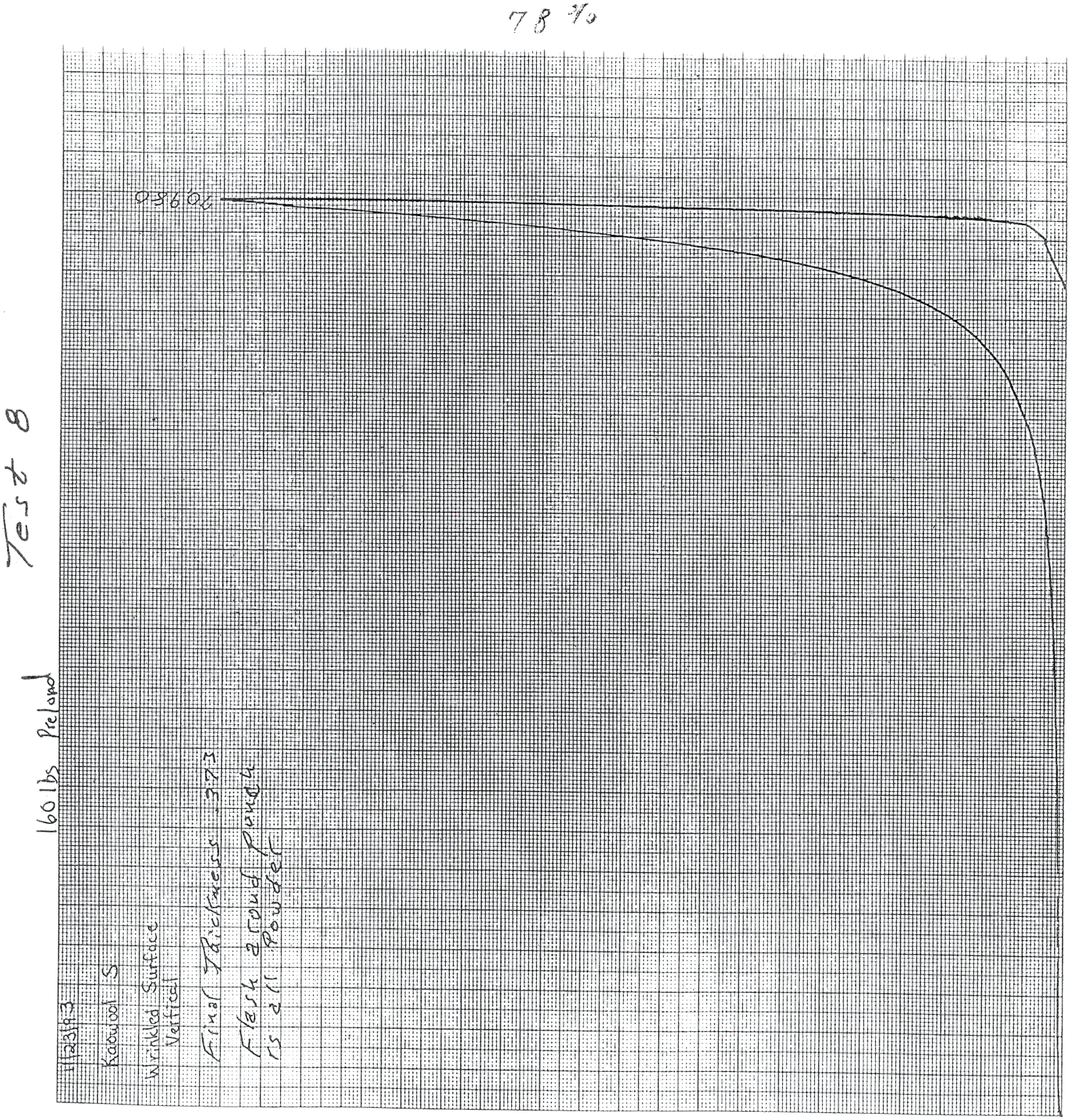


HEWLETT-PACKARD 9270-1024

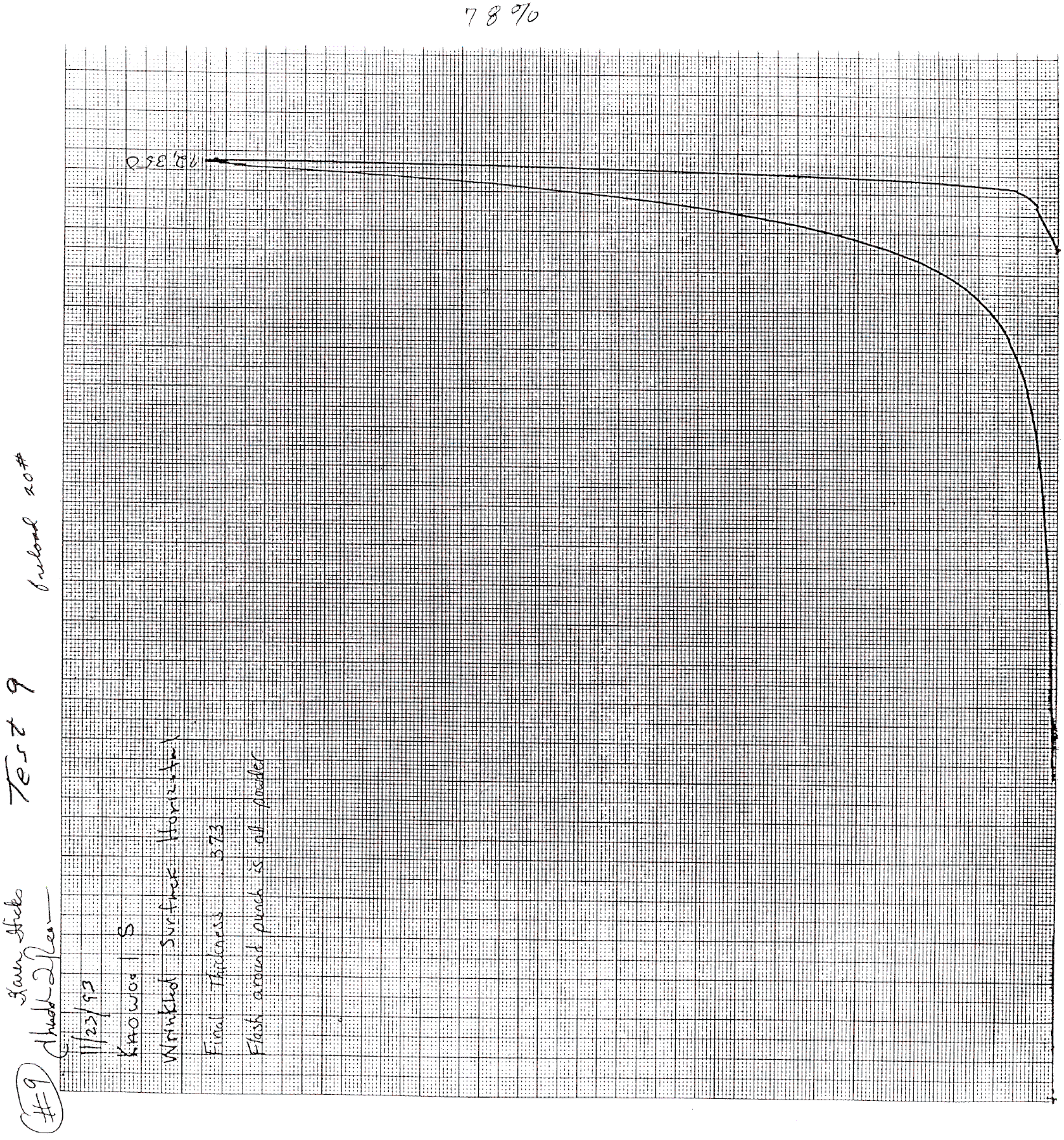

78 %
20660
Test 6
20# Preload
Karen Hicks
11/23/93
Cane Fiberboard
Black surface vertical to punch face
"Flush approximately 1/2" up side of punch"
Final thickness .385
.385
.070
.080

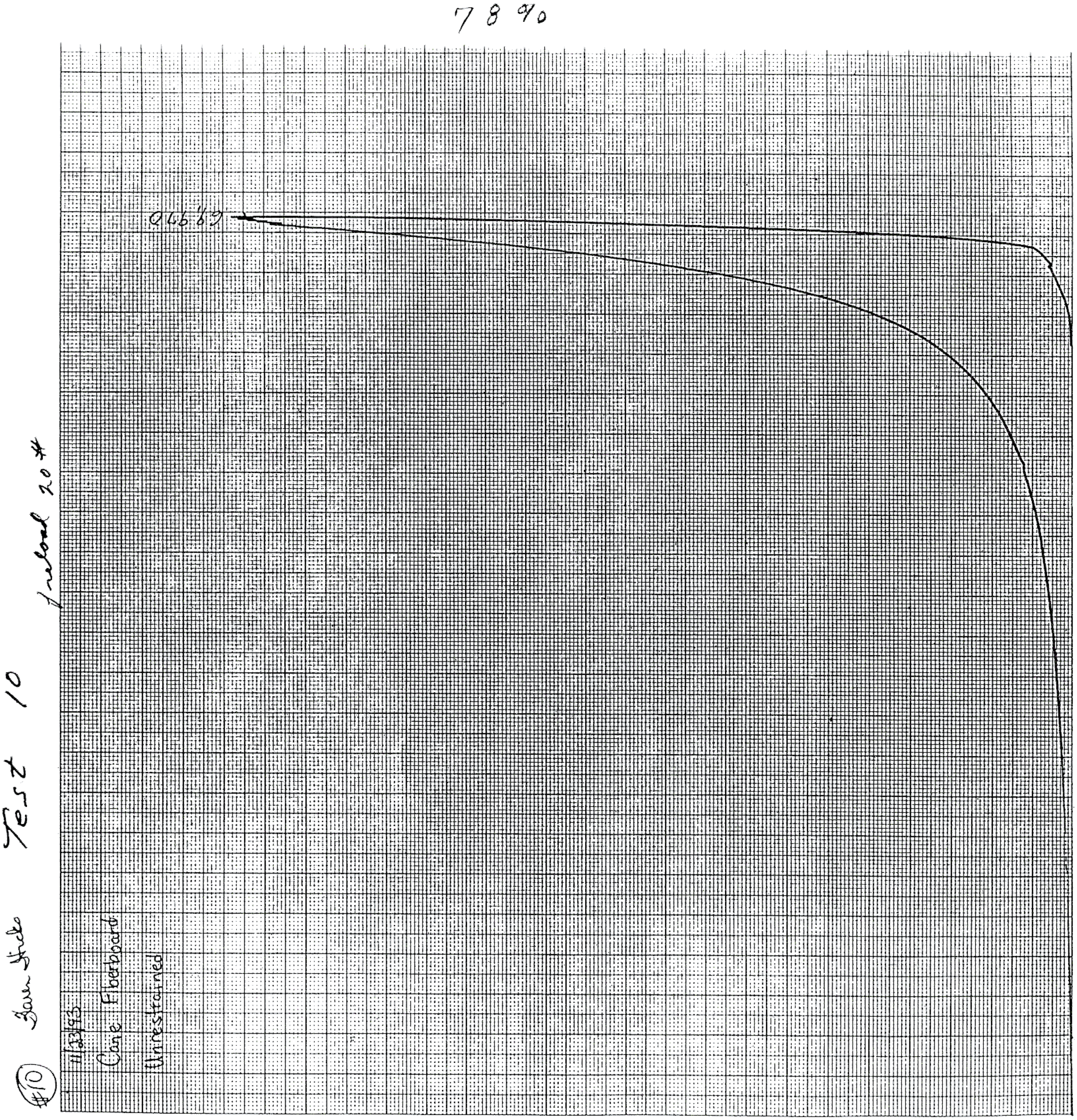
6

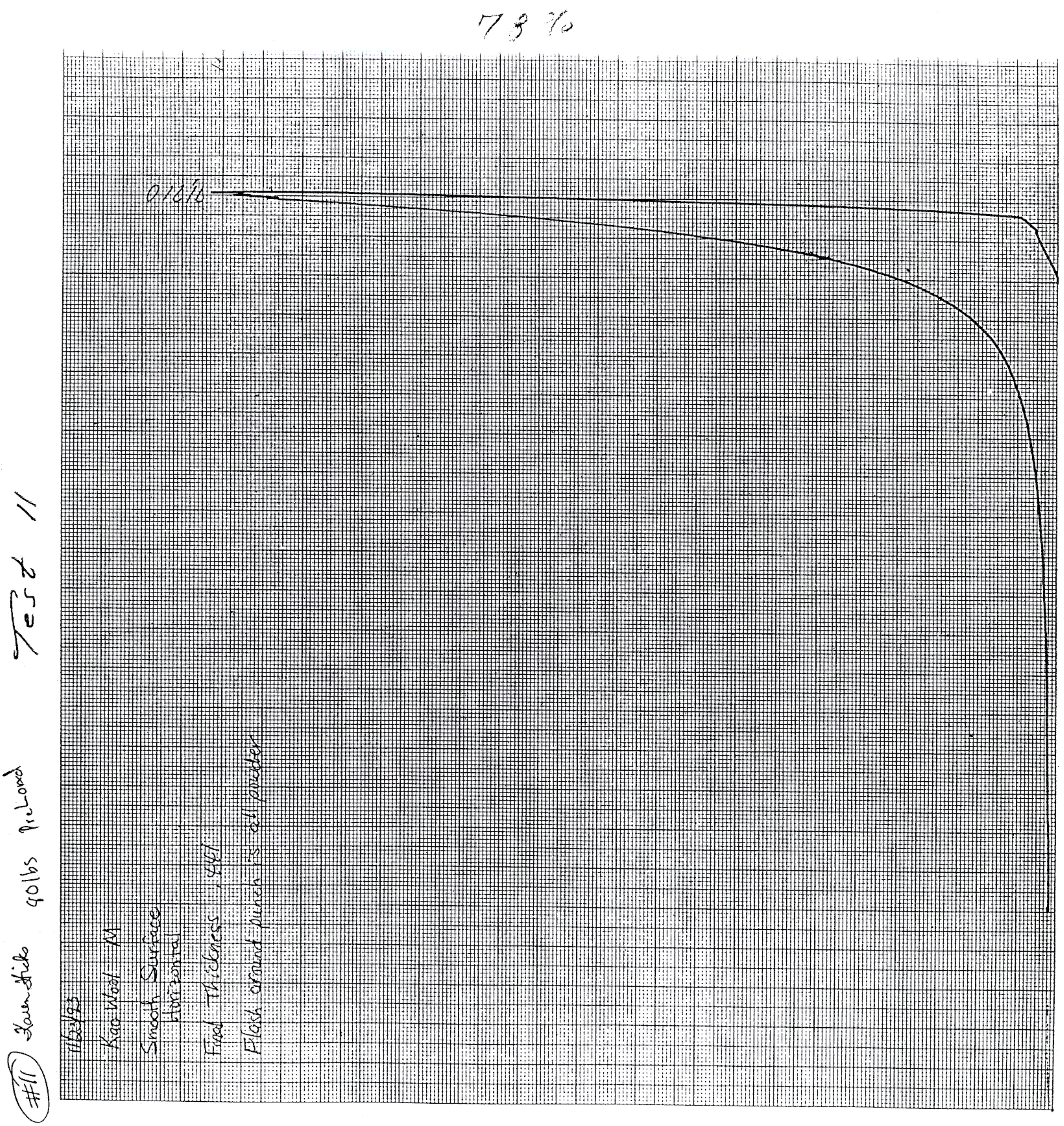

78%
086%
Test 7
20# Preload
Karen Hicks
11/23/93
Kaowool S
Wrinkled Surface
Horizontal
Flash ≈ .025" Thick
2-Sides
Final Thickness .355
Very brittle- Powdery
#7


78 %
70980
Test 8
160 lbs Preload
11/23/93
Kaowool S
Wrinkled Surface
Vertical
Final Thickness .373
Flash around punch
is all powder

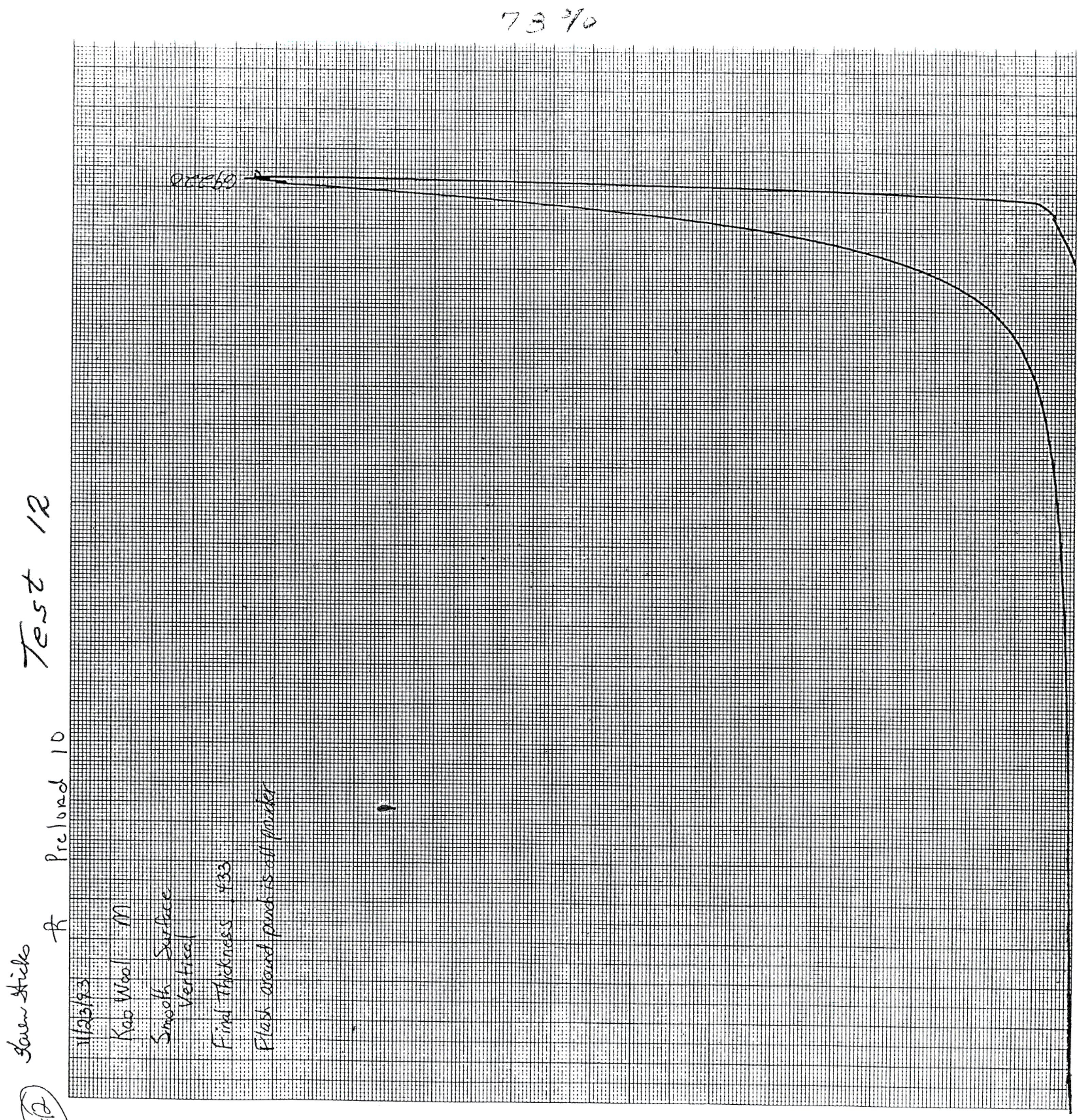
8


78%
92,350
Test 9
Preload 20#
#9
11/23/93
Kaowool I S
Wrinkled Surface Horizontal
Final Thickness .373
Flash around punch is all powder

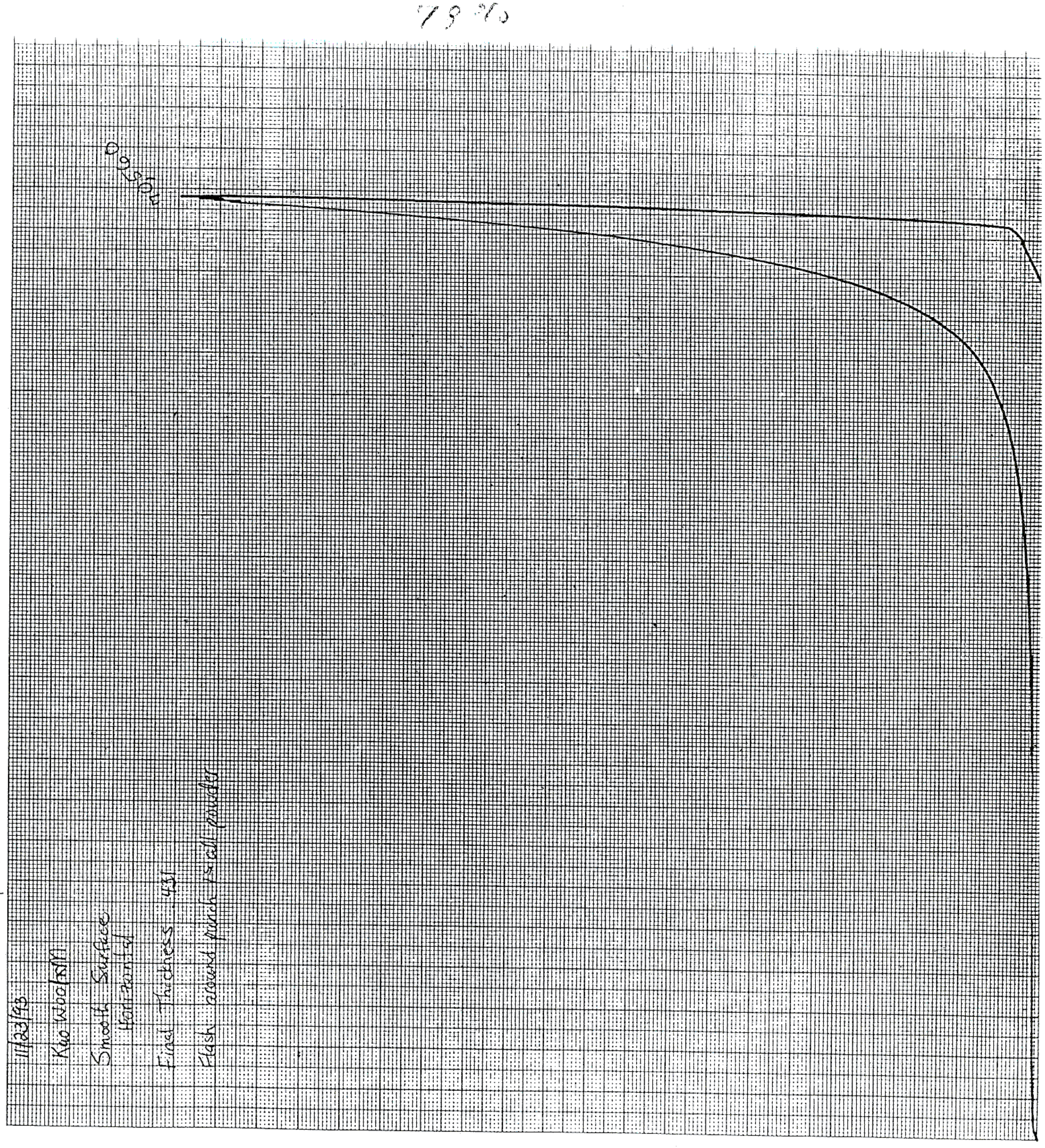

78 %
67990
Test 10
preload 20#
#10
11/23/93
Cane Fiberboard
Unrestrained

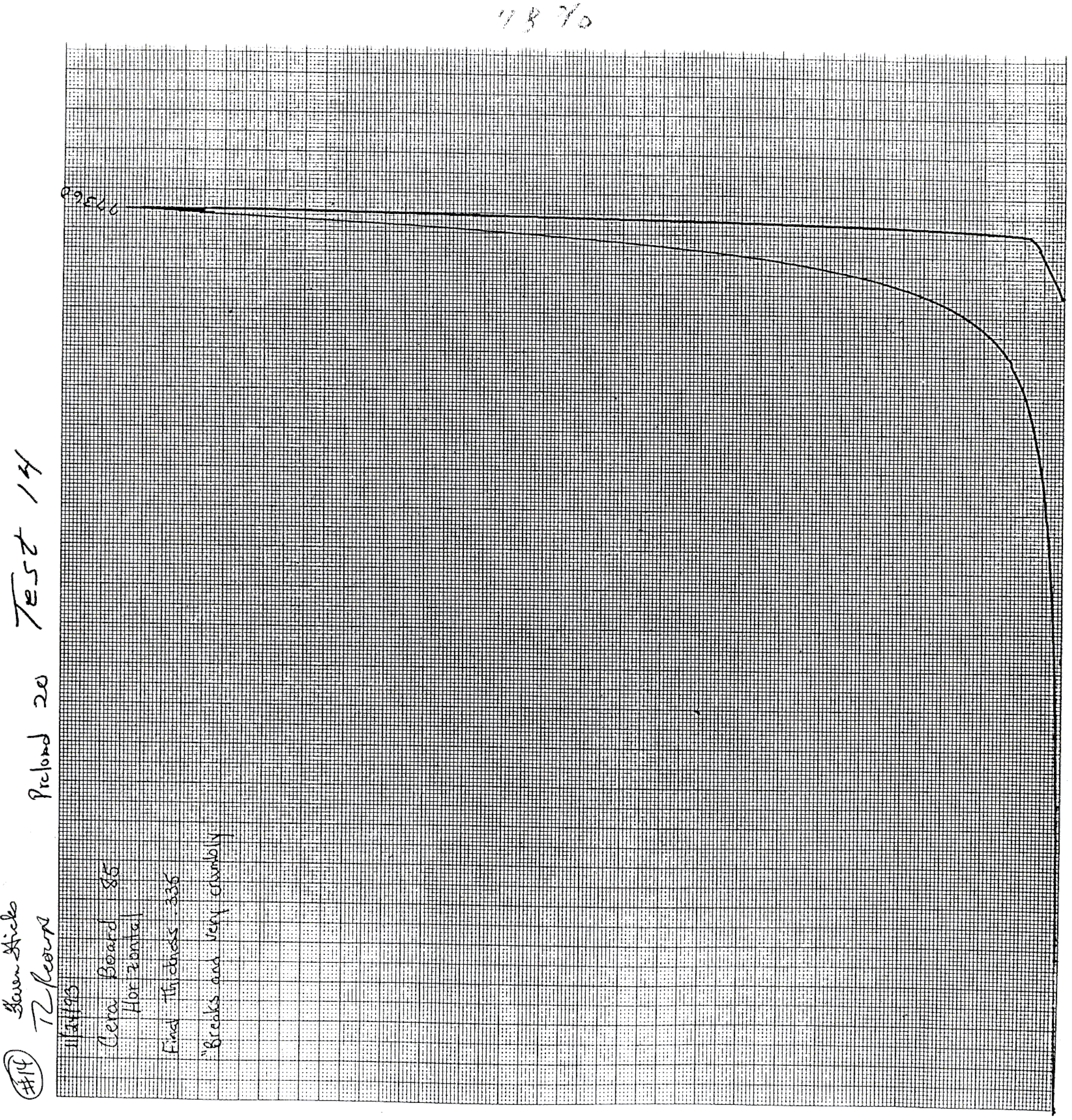


73%
Test 11
#11
40lbs PreLoad
11/23/93
Kao Wool M
Smooth Surface
Horizontal
Final Thickness .44"
Flash around punch is all powder

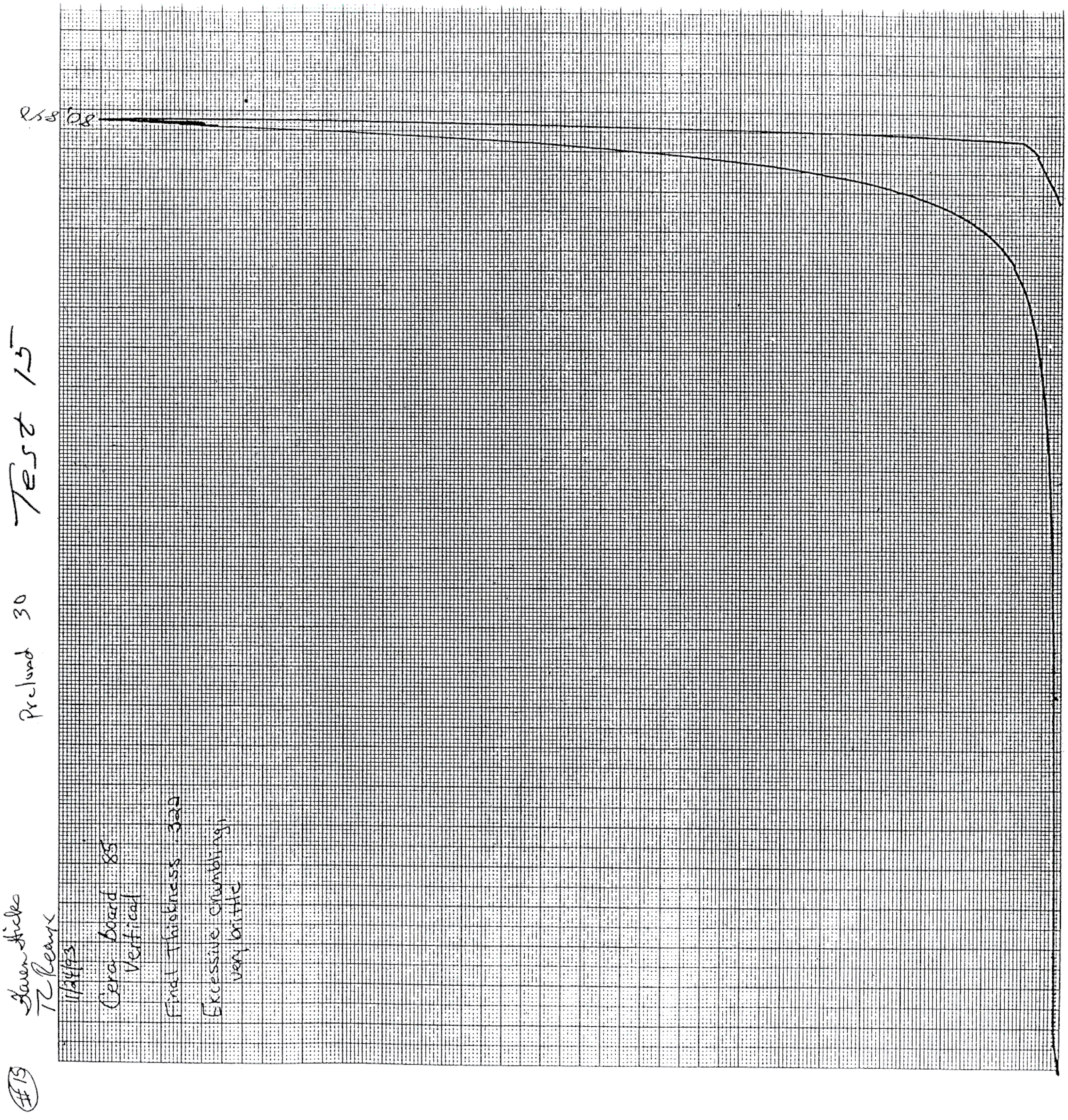


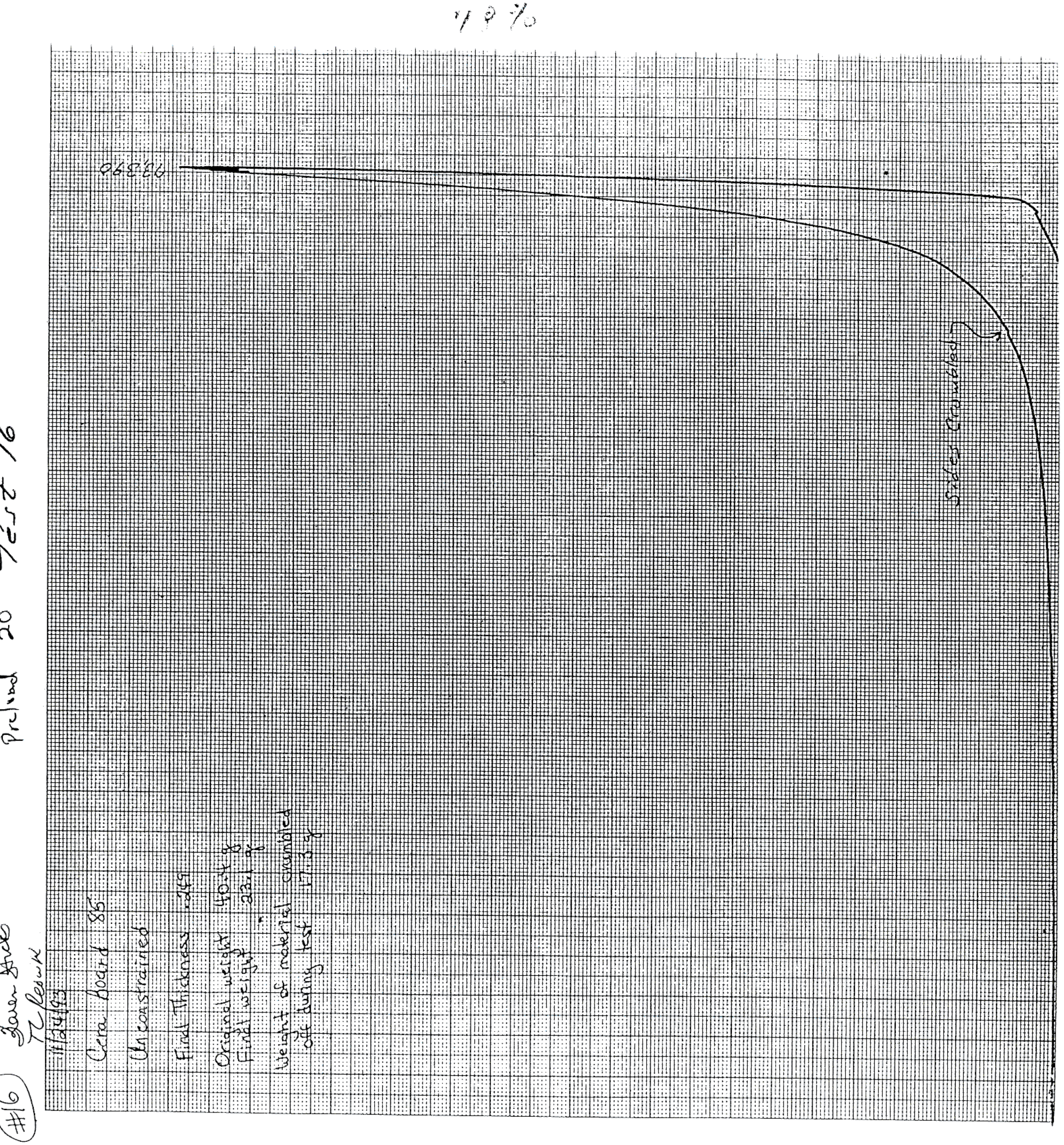
HEWLETT-PACKARD 9270-1024

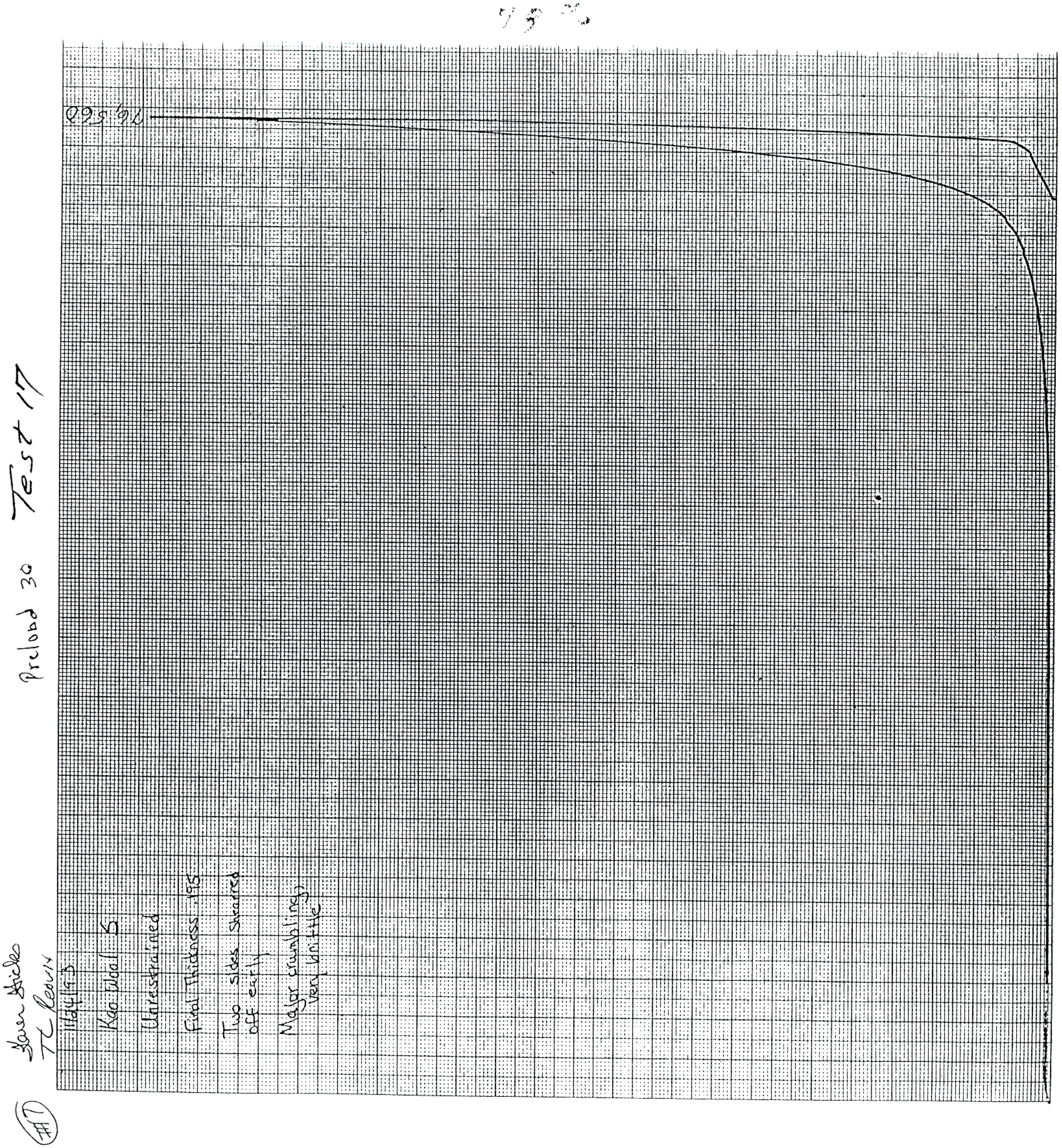

78%
Test 13
Preload 20
11/23/93
Smooth Surface
Horizontal
Final Thickness .431
Flash around punch & all powder
#13


#14
11/24/93
Cera Board 85
Horizontal
Find Thickness 336
"Breaks and very crumbly
Preload 20
Test 14

78%


Test 15
Preload 30
11/24/93
Cera Board 85
Vertical
Final Thickness .320
Excessive crumbling, very brittle
#15


#16
11/24/93
Cera Board 85
Unconstrained
Final Thickness .249
Original weight 40.4 g
Final weight 23.1 g
Weight of material crumbled off during test 17.3 g
Preload 20 Test 16
Sides Crumbled

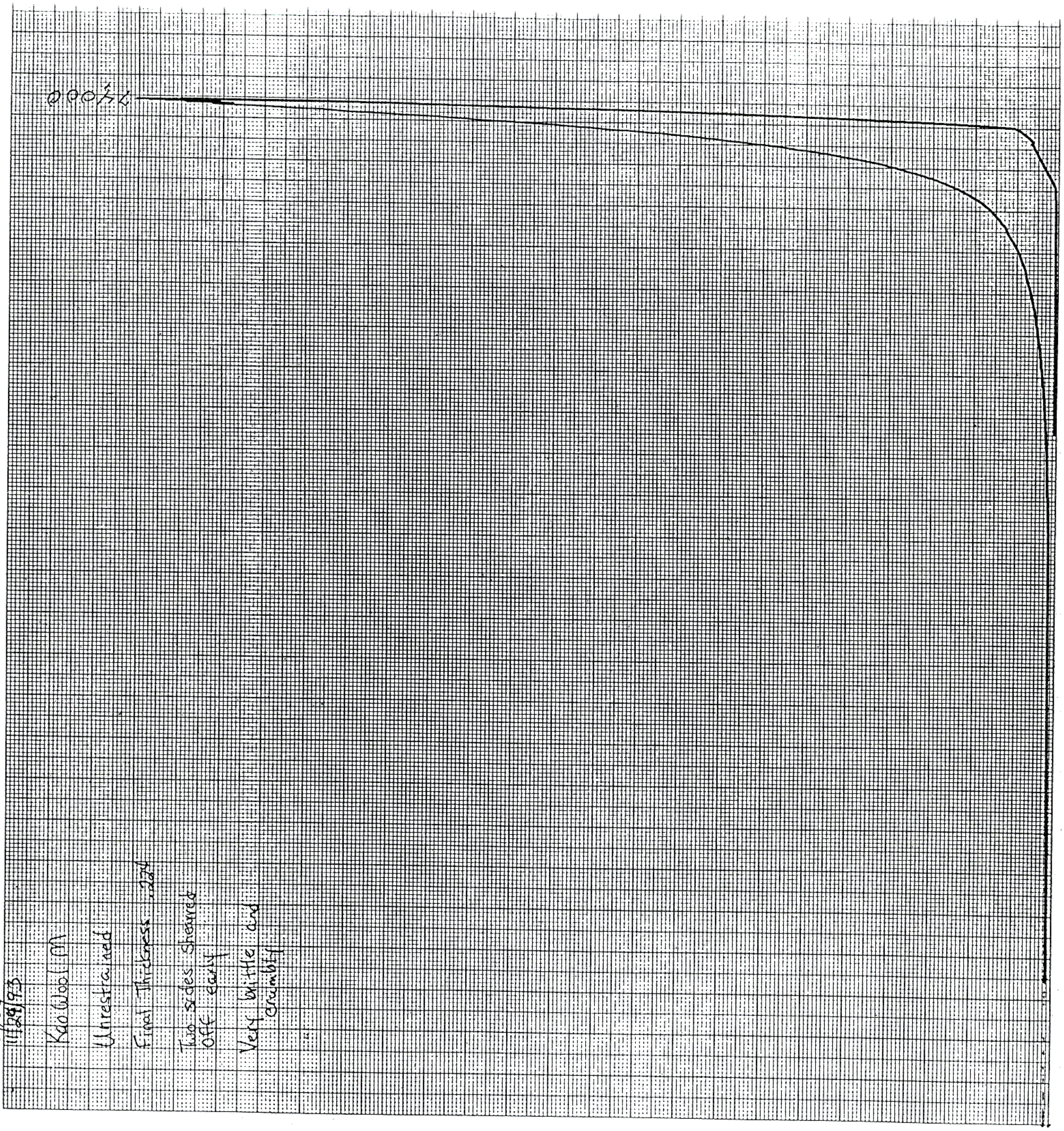

26,560
Preload 30
Test 17
11/24/93
Kao Wool 5
Unrestrained
Final Thickness .195
Two sides sheared off early
Major crumbling; very brittle
#17

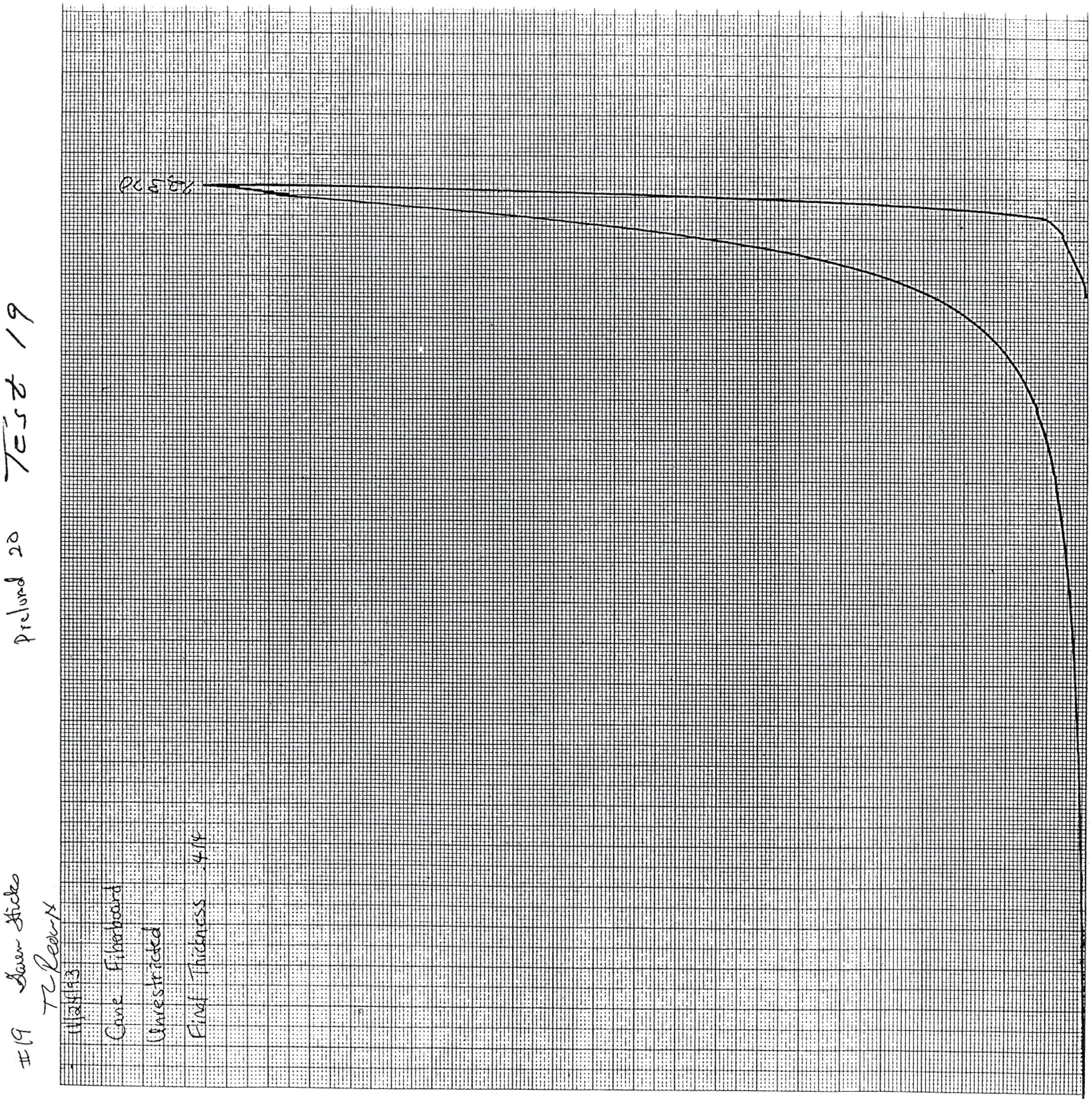
#18

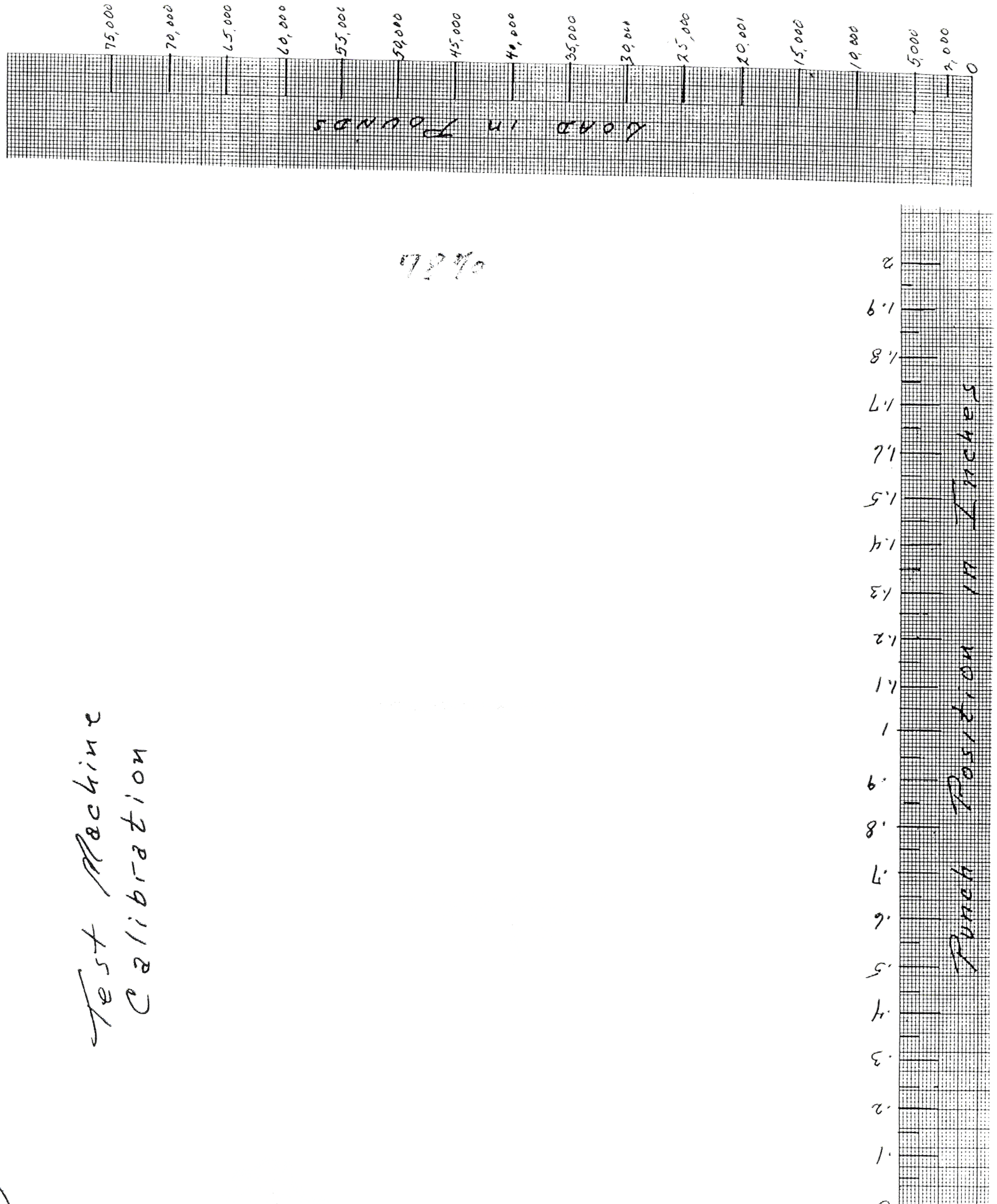
Test 18

Preload 30

Karen Hicks
T.C. Reavy




Test 19
Preload 20
#19 Saw Sticks
T Reeves
11/24/93
Cane Fiberboard
Unrestricted
Final Thickness .414


75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
2,000
0
Load in Pounds
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Punch Position in Inches
Test Machine
Calibration

(20)