SYSTEMS ANALYSIS PROJECT ADVISORY COMMITTEE

and

MAPPS USERS GROUP

SLIDE MATERIAL

March 24-25, 1988

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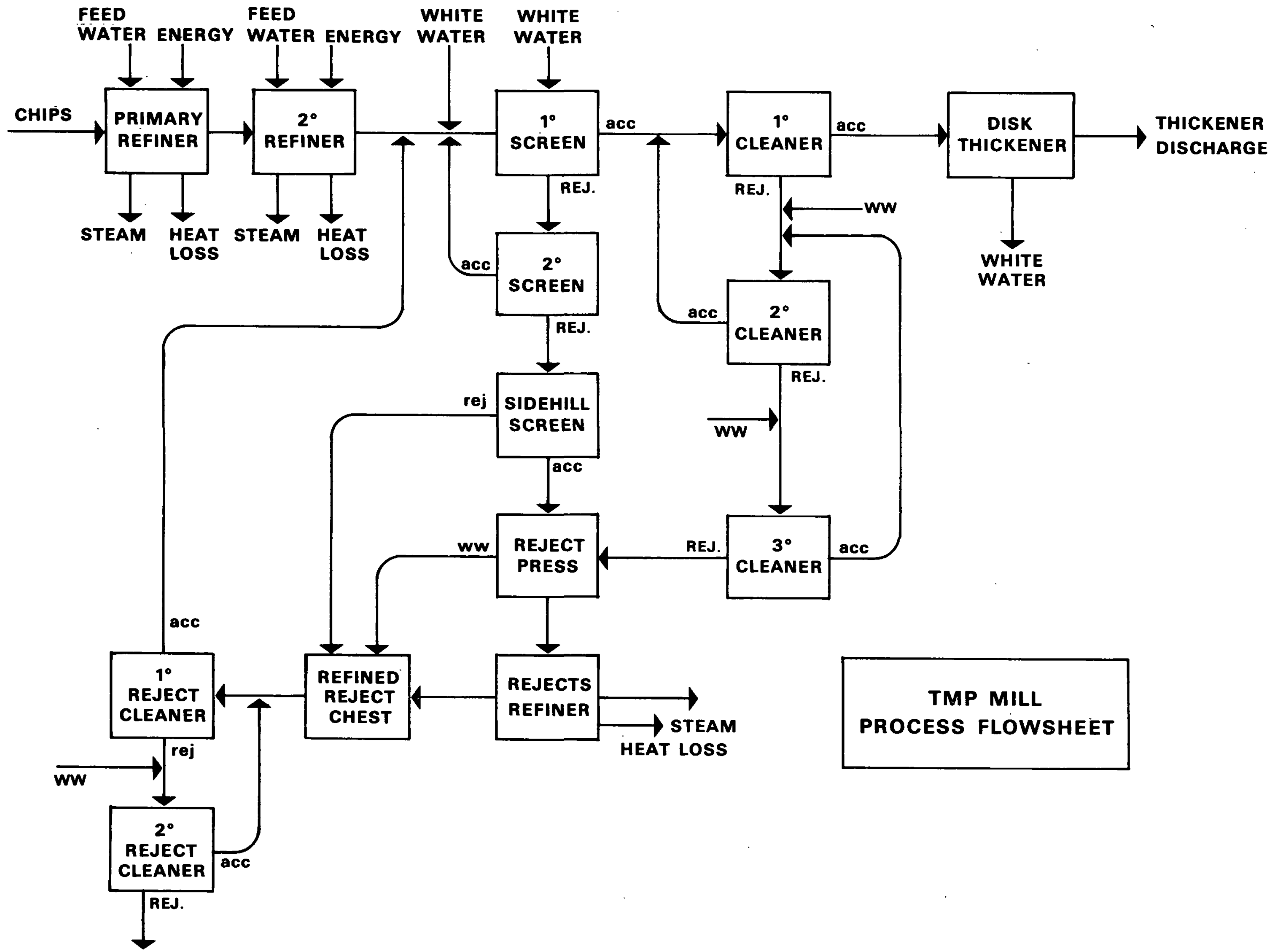
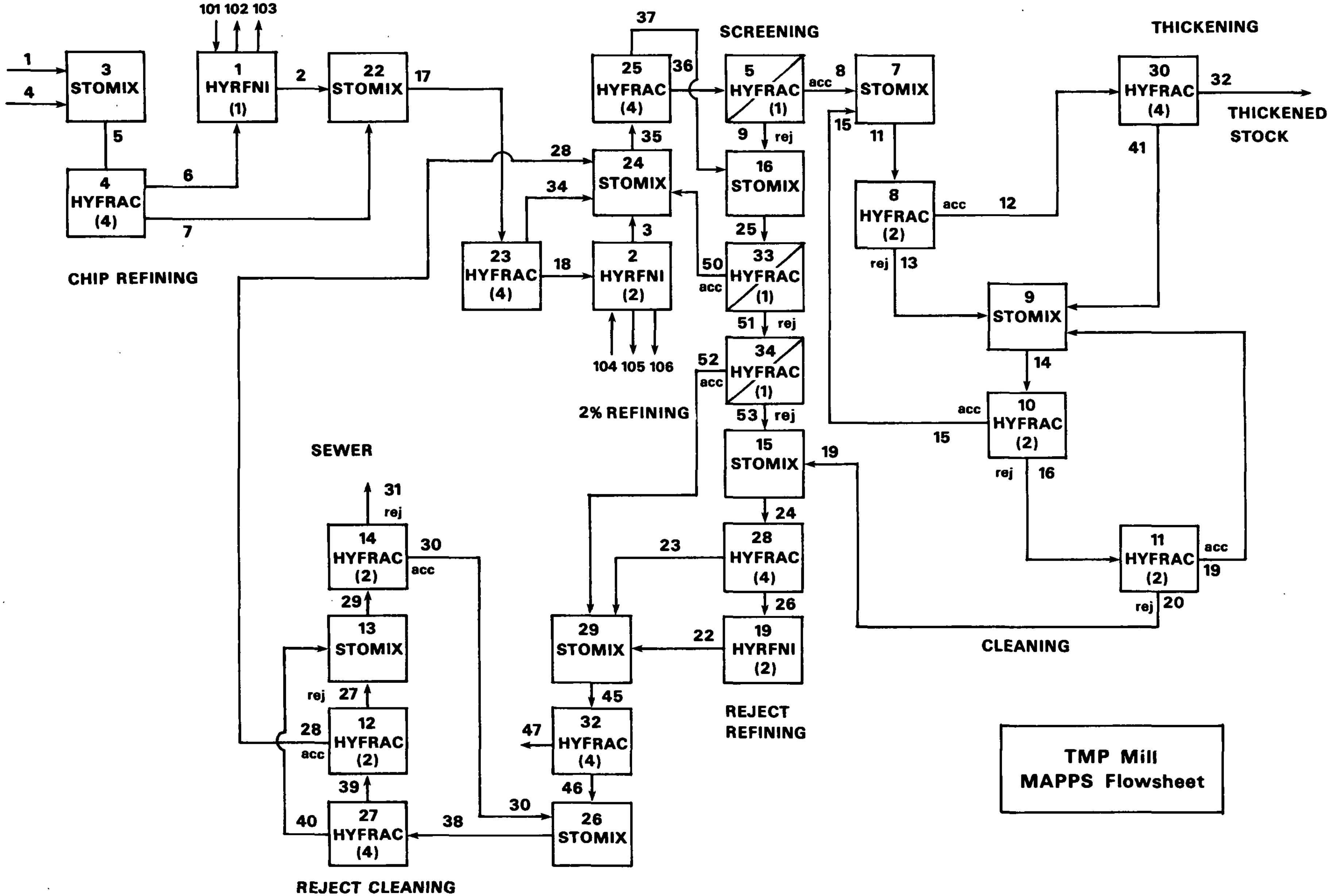
ADDITIONAL
SLIDE MATERIAL

March 24-25, 1988


FEED WATER
ENERGY
FEED WATER
ENERGY
WHITE WATER
WHITE WATER
CHIPS
PRIMARY REFINER
2° REFINER
1° SCREEN
acc
1° CLEANER
acc
DISK THICKENER
THICKENER DISCHARGE
STEAM
HEAT LOSS
STEAM
HEAT LOSS
REJ.
REJ.
WW
WHITE WATER
acc
2° SCREEN
acc
2° CLEANER
REJ.
REJ.
rej
SIDEHILL SCREEN
WW
acc
ww
REJECT PRESS
REJ.
3° CLEANER
acc
acc
1° REJECT CLEANER
REFINED REJECT CHEST
REJECTS REFINER
STEAM
HEAT LOSS
rej
WW
2° REJECT CLEANER
acc
REJ.
TMP MILL
PROCESS FLOWSHEET



TMP Mill
MAPPS Flowsheet

EXPERT SYSTEMS

RECOVERY BOILER TROUBLESHOOTING

STUDENT WORK

WAYNE MCADAMS A190

CAPTURE IPC EXPERTISE

DEVELOP STAND-ALONE VERSION

COUPLE MAPPS WITH ES

EXISTING PACKAGE NOKIA

COMPLETION BY SPRING 1989

EXPLORATORY ISSUES

CAD GRAPHICS

PROCESS CONTROL

STATUS

MARKETING

USER-FRIENDLY INTERFACE

PERFORMANCE ATTRIBUTES
- NEW MODELS
- VALIDATION
- IMPLEMENTATION

DEVELOPMENT ISSUES
- OPTIMIZER
- DYNAMIC SIMULATION
- EXPERT SYSTEMS

EXPLORATORY ISSUES
- CAD
- OTHERS

MARKETING

NEW CUSTOMERS 2

TOTAL CLIENTS 31

TAPPI VIDEO COURSE

PAPRICAN SYMPOSIUM
- DEMONSTRATION BOOTH
- PRESENTATION

USER-FRIENDLY INTERFACE

INITIAL RELEASE MID-JANUARY
- µMIP
- SALES ENCOURAGING

INTEGRATED INTERFACE

DEVELOP INTERACTIVE INTERFACE

STUDENT WORK

KEN THOMAS - A190

DEMONSTRATION

PERFORMANCE ATTRIBUTE

- MODEL DEVELOPMENT
  - DATA ANALYSIS
  - MODELS
- MODEL VALIDATION
- IMPLEMENTATION

DATA ANALYSIS

ALEXANDER & MARTON	YIELD, CWT, REFINING (CSF), WET PRESSING
TMP MILL	YIELD, REFINING, SCREENING, CLEANING
WMU	CALENDERING, SPECIES MIXTURES, MACHINE CONDITIONS
SETTERHOLM, FLEISCHMAN	ORIENTATION ANGLE, WET STRETCHING
KIBBLEWHITE, CLARK, ETC.	MODEL VALIDATION

ALEXANDER AND MARTON DATA

CONSTANTS
SPECIES, PULPING TYPE, KAPPA NO., BLEACHING

INDEPENDENT VARIABLES

CELL WALL THICKENESS (1.8, 3.5 μ)	CWT
YIELD (48-60%)	Y
REFINING (30-700 CSF)	CSF
WET PRESSING PRESSURE (0-9200 psi)	P

DEPENDENT VARIABLES

SHEET PROPERTIES

DENSITY

MODULUS

BREAKING LENGTH

BURST, TEAR

RUPTURE ENERGY

ELONGATION AT BREAK

SCATTERING COEFFICIENT

SINGLE FIBER PROPERTIES

MODULUS

BREAKING LENGTH

FIBRIL ANGLE

SWELLING

CROSS SECTIONAL AREA

MODELS DEVELOPED FROM A&M DATA

HANDSHEET PROPERTIES:

DENSITY	(JONES)
MODULUS	(PAGE)
BREAKING LENGTH	(PAGE)
BURST	(JONES, VANDENAKKER)
TEAR, RUPTURE ENERGY	(JONES)
STRAIN AT BREAK	(JONES)
SCATTERING COEFFICIENT	(MALMBERG)

FIBER PROPERTIES:

EFFECTIVE FIBER MODULUS	(JONES)
EFFECTIVE FIBER TENSILE	(JONES)

PROCESS:

SURFACE AREA VS. CSF
BONDING COEFFICIENT
RELATIVE BONDED AREA
COMPRESSIBILITY COEFFICIENTS

SHEET DENSITY (ρ)

$$\frac{1}{\rho} = \frac{1}{\rho_u} + \left(\frac{1}{\rho_l} - \frac{1}{\rho_u} \right) \frac{1}{S_b 2}$$

$$\rho_u = \frac{1}{.764 + .000477\ \mathrm{CSF} + .1146\ (\mathrm{CWT}-1.5)}$$

$$\rho_l = \frac{1}{\frac{1}{\rho_u} - .05866\ \mathrm{CSF} + .0783\ Y + 43.142}$$

$$\rho_{l_m} = .05\ (\mathrm{CWT} - .8) + .002\ (Y - 48)$$

$S_b \approx 1$ at high CSF, low wet pressing thick walled vessels

$\rho_u \sim .8$ to 1.1 g/cc

$\rho_l \sim .06$ to $.3$ g/cc

HYDRODYNAMIC SPECIFIC SURFACE (S_h)

$$S_h = 95.7 - .12\ \mathrm{CSF}\ (m^2/g)$$

BONDING AREA

$$S_{bo} = C_i \cdot S_h$$

$C_1 = .0734 - .00654\ Y$ Y (%)

WET PRESSING EFFECTS

$$S_b = S_{bo}\, f(\rho)$$

$$f(\rho) = 1 + M\rho^N$$

$$M = e^{.144 + .00177\ CSF}$$

$$N = .0003\ CSF - .000515\ Y$$

SHEET MODULUS

- CONFIRMED PAGE MODEL

$$E = \left(\frac{E_f}{3}\right)\left(\frac{\rho}{\rho_f}\right)\left(1 - \frac{k}{RBA}\right) \quad \text{(Page/Nissan)}$$

$$k = \frac{W}{L}\left(\frac{E_f}{2G_f}\right)^{\frac{1}{2}}$$

$$RBA = \frac{\rho - \rho_1}{\rho_u - \rho_1}$$

SHEET MODULUS

$$E = \frac{E_f}{3} \left(\frac{\rho - \rho_1}{\rho_u} \right) \left(1 - \frac{k}{RBA} \right) \quad \text{(Modified)}$$

$$E = E_o (\rho - \rho_o)$$

$$E_o = \frac{E_f}{3\rho_u}$$

$$\rho_o = \rho_1 + (\rho_u - \rho_1) \left(\frac{W}{L} \right) \left(\frac{E_f}{2G_f} \right)^{\frac{1}{2}}$$

SHEET MODULUS

$E = 10.6 (\rho - .19)$ LINEAR FORM (MALMBERG) ($R^2 = .95$)

$E = 13.6 \left(1 - \frac{.4}{\rho + .4}\right)$ NONLINEAR FORM ($R^2 = .95$)

$$\frac{E_f}{3\rho_u} = E_o = \text{CONSTANT}$$

$$E_f = 3\ E_o\ \rho_u = \frac{31.8}{.746 + .000477\ CSF + .115\ CWT}$$

DID NOT FIT SINGLE FIBER MODULUS DATA

$$\frac{E_f}{3\rho_u CWT} \approx \text{CONSTANT}$$

FIBER MODULUS

$$E_f = 172.4 + 0.55\ (CWT \cdot \rho_u \cdot g)\quad \frac{Kg}{mm^2}\ (R^2 = .89)$$

EFFECTIVE FIBER MODULUS IN SHEET E_f^*

$$E_f^* = \frac{58\ (E_f - 172.4)}{CWT\ g}$$

$$\frac{E_f^*}{3\rho_u} = 10.6 = E_o$$

BREAKING LENGTH (Z)

- PAGE MODEL CONFIRMED

$$\frac{1}{Z} = \frac{9}{8Z_f} + \frac{12A\rho_u g}{RBA\ b\ p\ L}\quad \text{(PAGE)}$$

$$Z_f = \frac{P_1(\rho - P_3)}{(\rho + P_2)}\qquad (R^2 = .85)$$

$P_1 = 24.51 + .414\ Y - 3.5\ CWT$
$P_2 = 3.37$
$P_3 = .086$

FIBER TENSILE (Z_f)

$$Z_f = \frac{9}{8} P_1 = \frac{9}{8} (24.5 + .414\ Y - 3.5\ CWT)$$

-Z_f does not fit single fiber data well

BURST (B)

VAN DEN AKKER MODEL

$$B = C\,(E_1)^{\frac{1}{2}}\,\frac{(T_{MD} + T_{CD})}{2}$$

$$B = 5.1\,(E_1)^{\frac{1}{2}}\,Z \qquad (R^2 = 0.90)$$

LINEAR MODEL

$$B = -15.1 + 10.175\,Z \qquad (R^2 = .92)$$

$$C = 5.6 - .127\,CWT\,(1 + .0015\,CSF)$$

STRAIN AT BREAK, (E_1)

$$E_1 = 0.85 + .02677\,Z - .177\,E \qquad (R^2 = .85)$$

RUPTURE ENERGY (R.E.)

$$R.E. = 392 - 308E_1(1 - .237\,Z) \qquad (R^2 = .95)$$

TEAR

$$Tear = 296 - 14\,E - B - \frac{20.7}{\rho} \qquad (R^2 = .8)$$

SCATTERING COEFFICIENT (SL)

$$SL_u - SL = SL_k\,(\rho - \rho_1) \qquad (R^2 = .94)$$

$$SL_u = 874 + .04\ CSF - 77.5\ CWT$$

$$SL_K = 928 - 98\ CWT - 6.6\ Y$$

POROSITY (POR)

$$POR = A_1 + A_2/CSF$$

$$A_1 \approx 0$$

$$A_2 \approx 12000$$

OTHER EFFECTS

- APPARENT FIBER CRUSHING, DAMAGE AT HIGH PRESSURE
- REDUCED DENSITY, MODULUS, TENSILE
- NOT ADEQUATELY ACCOUNTED FOR

FLEISCHMAN DATA (IPC)

- SHEET ANISOTROPY (WET STRETCH, ORIENTATION)
- MODULUS (E_x, E_y, E_z)
- TENSILE (Z_x, Z_y, Z_z)
- COMPRESSIVE STRENGTH (C_x, C_y)
- SINGLE SPECIES

MODULUS

$$E_x/E_y = R + .335 - .583\ WS + 0.708\ WS \cdot OR + 0.635 OR^2 \quad (R^2 = .95)$$

$$E_x/\rho = 6.84 + 5.69\ OR + 0.927 WS \cdot OR \qquad (R^2 = .96)$$

$$E_y/\rho = 14.79 - 4.18\ OR - .288 OR \cdot WS \qquad (R^2 = .98)$$

E_z - interactions between WS, OR and ρ

$$E_z = .257 + (.124\ WS - 1.106)\ \rho$$

$$+ (1.339\ .02936\ OR - .0241\ WS)\ \rho^2$$

TENSILE

Z_x, Z_y similar to E_x, E_y

or

$$Z_x = -6.97 + 6.56\ E_x \qquad (R^z = .90 \text{ con coef. } = .95)$$

$$Z_y = 3.56 + 5.43\ E_y \qquad (R^z = .94 \text{ con coef. } = .97)$$

$$Z_z = .220 + 1.86 \cdot E_z \qquad (R^2 = .943)$$

COMPRESSIVE STRENGTH

(HABEGER, WHITSITT MODELS)

$$C_x = 3.38 + 5.51\ E_x{}^{.75}\ E_z{}^{.25} \qquad (R^2 = .95)$$

$$C_y = 3.46 + 4.76\ E_x{}^{.75}\ E_z{}^{.25} \qquad (R^2 = .92)$$

OTHER MODELS UNDER DEVELOPMENT

- IPC DATA (BRIAN BURGER)
  - EFFECTS OF REFINING, SPECIES
  - ANISOTROPY, MODULUS, TENSILE

- WMU DATA
  - CALENDERING MACHINE EFFECTS
  - PAUL ROZIK (A190 WORK)

BRIGHTNESS

$C_K = C_{Lig}X_{Lig} + C_{cell}X_{cell} + C_{ext}X_{ext}$ (cm^2/g)

$C_{cell} = 7.5$

$C_{ext} = 1.0$

$C_{Lig} = 250$ to 350

$$\text{Brightness} = \frac{C_K}{S_K} + 1 - \left(\left(\frac{C_K}{S_K}\right)^2 + 2\left(\frac{C_K}{S_K}\right) \right)^{\frac{1}{2}}$$

OTHER MODELS

- OTHER COMPRESSIVE PROPERTIES (RING CRUSH, ETC.)
- FORMATION (GRABER & GOTTSCHING)
- LAMINATES
- EFFECTS OF UNUSUAL PULPING CONDITIONS

DENSITY MODEL VALIDATION

- FITS DATA OF

KIBBLEWHITE - KRAFT 4 NEW ZEALAND BEECH FPEICES (RANDOM)

FLEISCHMAN - BLEACHED KRAFT - DOUGLAS FIR, SPRUCE MIXTURES

TMP MILL (ASSUMED 100% YIELD, SPECIES UNKNOWN)

CLARK BLEACHED SULFITE (SPECIES UNKNOWN)

PERFORMANCE ATTRIBUTES

YIELD

KAPPA

$\overline{L}$

σ_L

$\overline{W}$

σ_W

K-FACTOR

C_K ABSORPTION COEFFICIENT

R ANISOTROPY RATIO

ρ_V COEFFICIENT OF VARIATION IN SHEET DENSITY

ρ_f

CWT

E_f

Z_f

ρ_f

DATABASE DEVELOPMENT

SOURCES:

- ISENBERG DATA
- IPC DATA SUPPLEMENT
- FPL
- LITERATURE

REQUIRE:

SPECIES

E_f

Z_f

ρ_f

BENDING MODULUS

CWT

$\overline{L}$

$\overline{W}$

COARSENESS

COMPOSITION:
LIGNIN
CELLULOSE
HEMICELLULOSE

MODEL VALIDATION

TMP MILL DATA

FLOWSHEET DEVELOPED

MODELS VALIDATED

PROCESS MODELS

$$\overline{L} = \frac{A_1}{A_2} + (L_{in} - \frac{A_1}{A_2}) e^{-A_1 ZP}$$

$$\sigma_1 = A_3 - A_4/\overline{L}$$

$$ZP = 10^{(NSP - A_p)/B_p}$$

(similar for $\overline{W}$)

$$S_h = 1 - \frac{1}{K} \sum_{1=1}^{n} X_i \ln \left(\frac{L_i}{2.4} \right)$$

$$K = K_o e^{K_2 \cdot NSP}$$

$$k_2 = f(NSP, \text{Consistency}, K_o)$$

$S_h = a \ln (CSF) + b$ (high yield)

SCREENING AND CLEANING-SEPARATION EFFICIENCIES

HANDSHEET MODELS - VENKATESH

PROPERTY = f(long fibers, shives, CSF)

PROPERTY	VENKATESH	JONES*
BULK	10-20% LOW TOO SENSITIVE TO SHIVES	CLOSE NOT AS SENSITIVE
BREAKING LENGTH	TOO SENSITIVE TO SHIVES	NOT AS SENSITIVE
BURST	50% LOW	CLOSE
TEAR	REASONABLE	2 X TOO HIGH
SCATTERING	REASONABLE	2 X TOO LOW
OPACITY	CLOSE	NM
GURLEY POROSITY	INACCURATE	REASONABLE
ELONGATION AT BREAK	NM	REASONABLE
RUPTURE ENERGY	ND	ND
DRAINAGE TIME	ND	ND
WET WEB STRENGTH	ND	ND
ABSORPTION COEFFICIENT	NM	NM
Z-D TENSILE	NM	REASONABLE+

NM NO MODEL
ND NO DATA
* EXTRAPOLATION TO 100% YIELD
+ 8% SHRINKAGE

PROCESS MODELS

CSF	REASONABLE
FIBER LENGTH DISTRIBUTION	REQUIRED MINOR MODIFICATION
SHIVES	GOOD MATCH
L-FACTOR	GOOD MATCH
SEPARATIONS	REASONABLE EXCEPT AFTER MANY STAGES
CONSISTENCIES	REASONABLE EXCEPT AFTER MANY STAGES

MODIFICATIONS

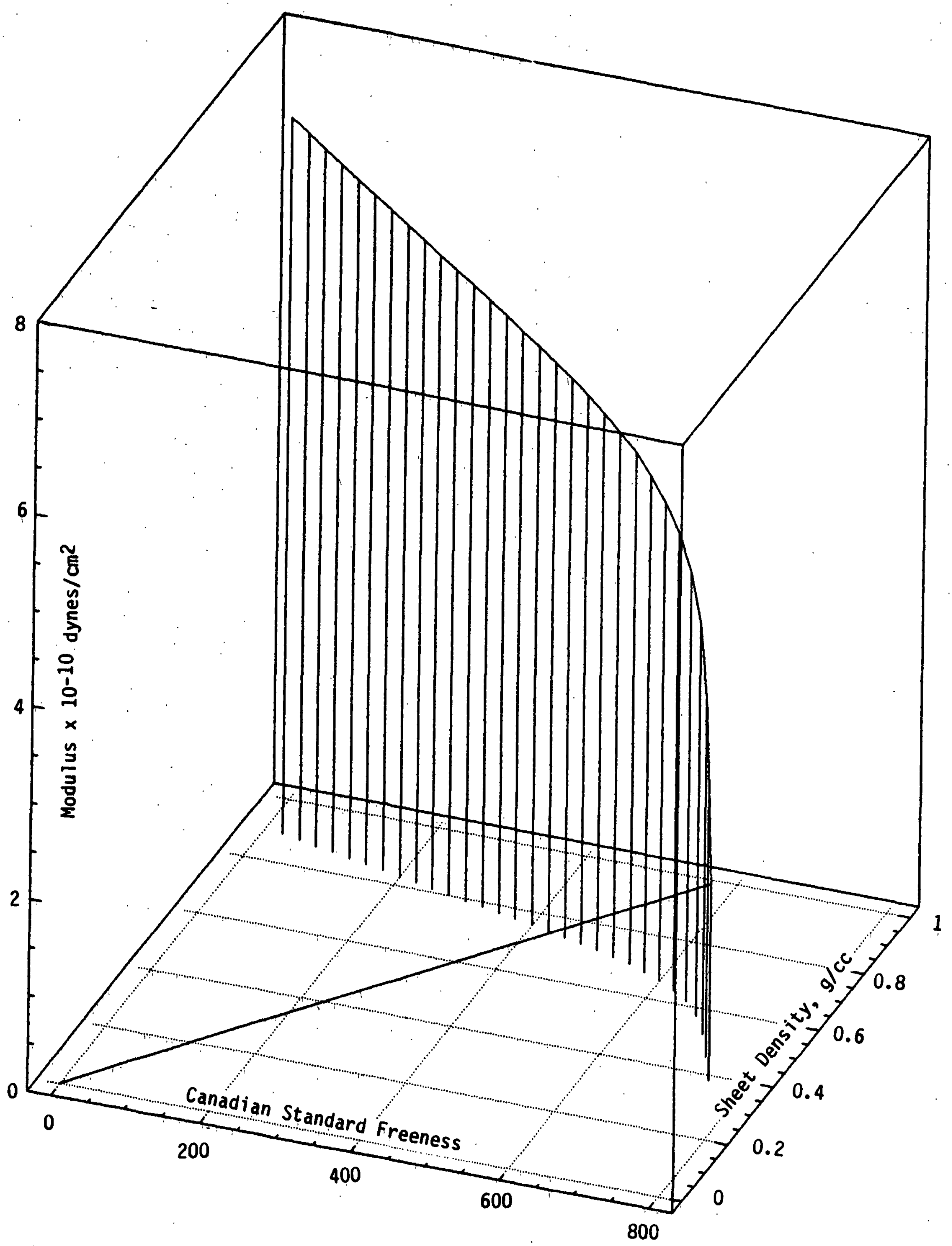
ALTER LOG NORMAL DISTRIBUTION (HYRFN1)

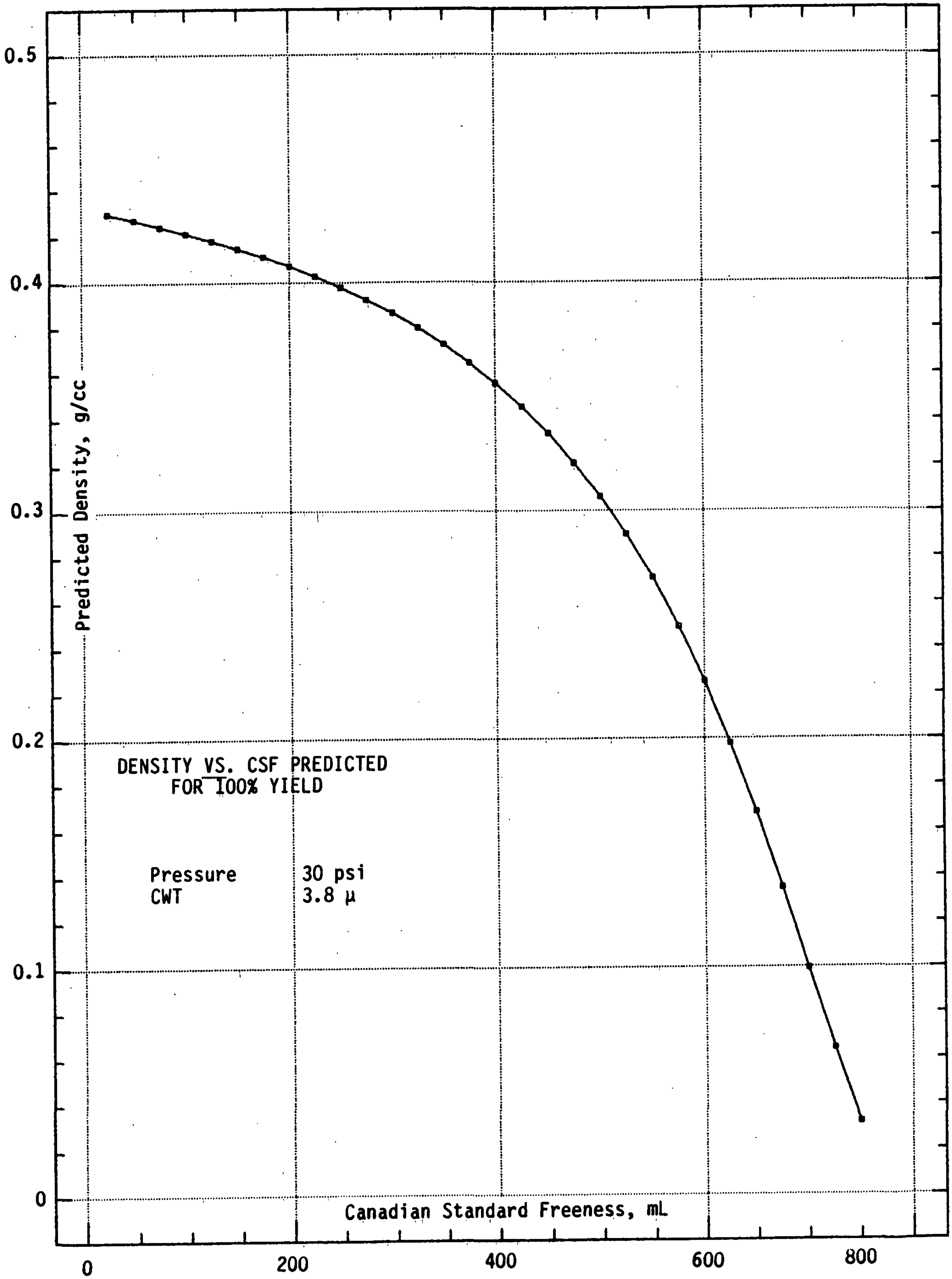
LOCAL REVERSIBILITY IN SEPARATIONS (HYFRAC)

FINES LEAKAGE OPTION (HYFRAC)

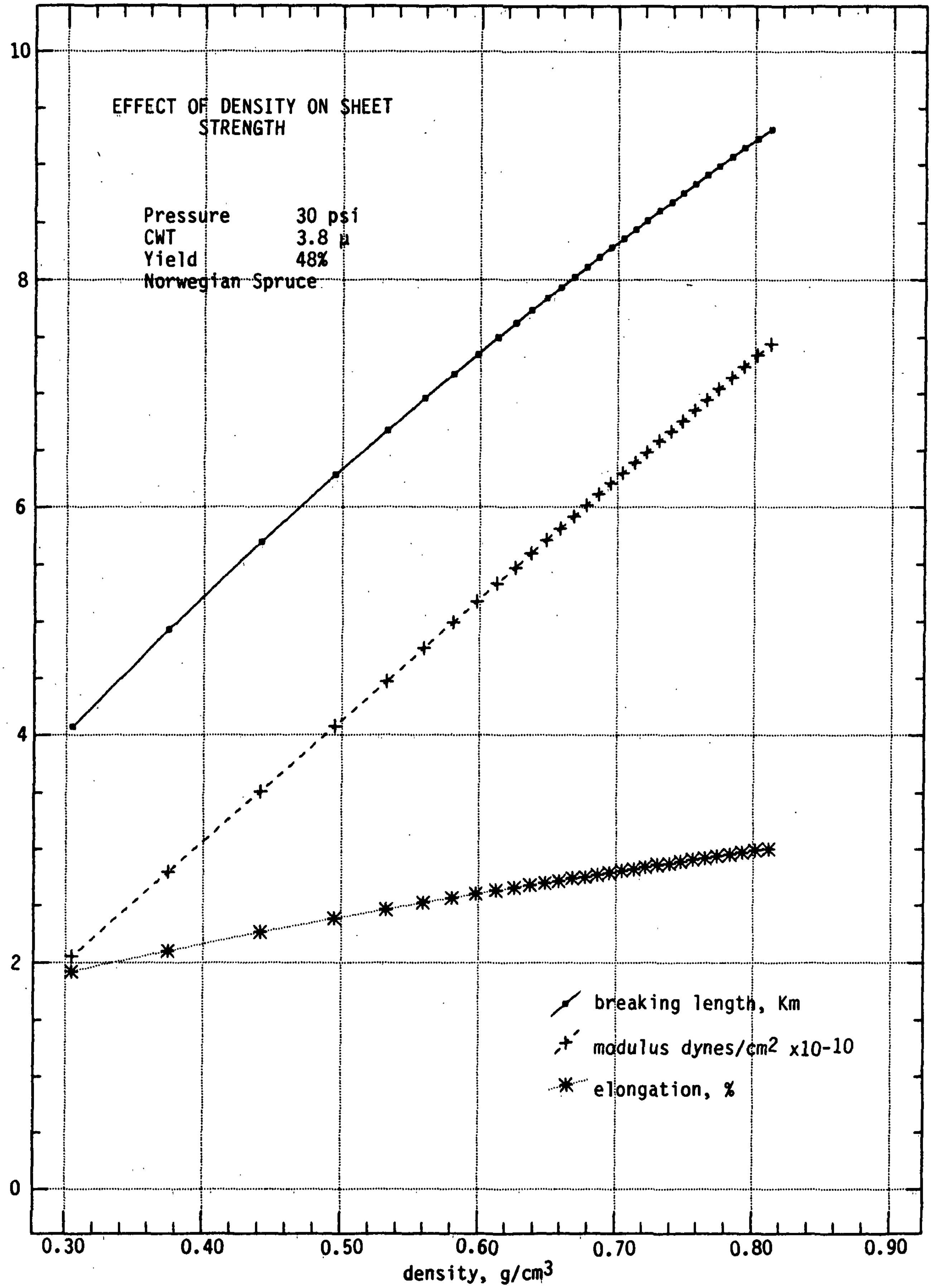
SHEET MODULUS - DENSITY AND FREENESS

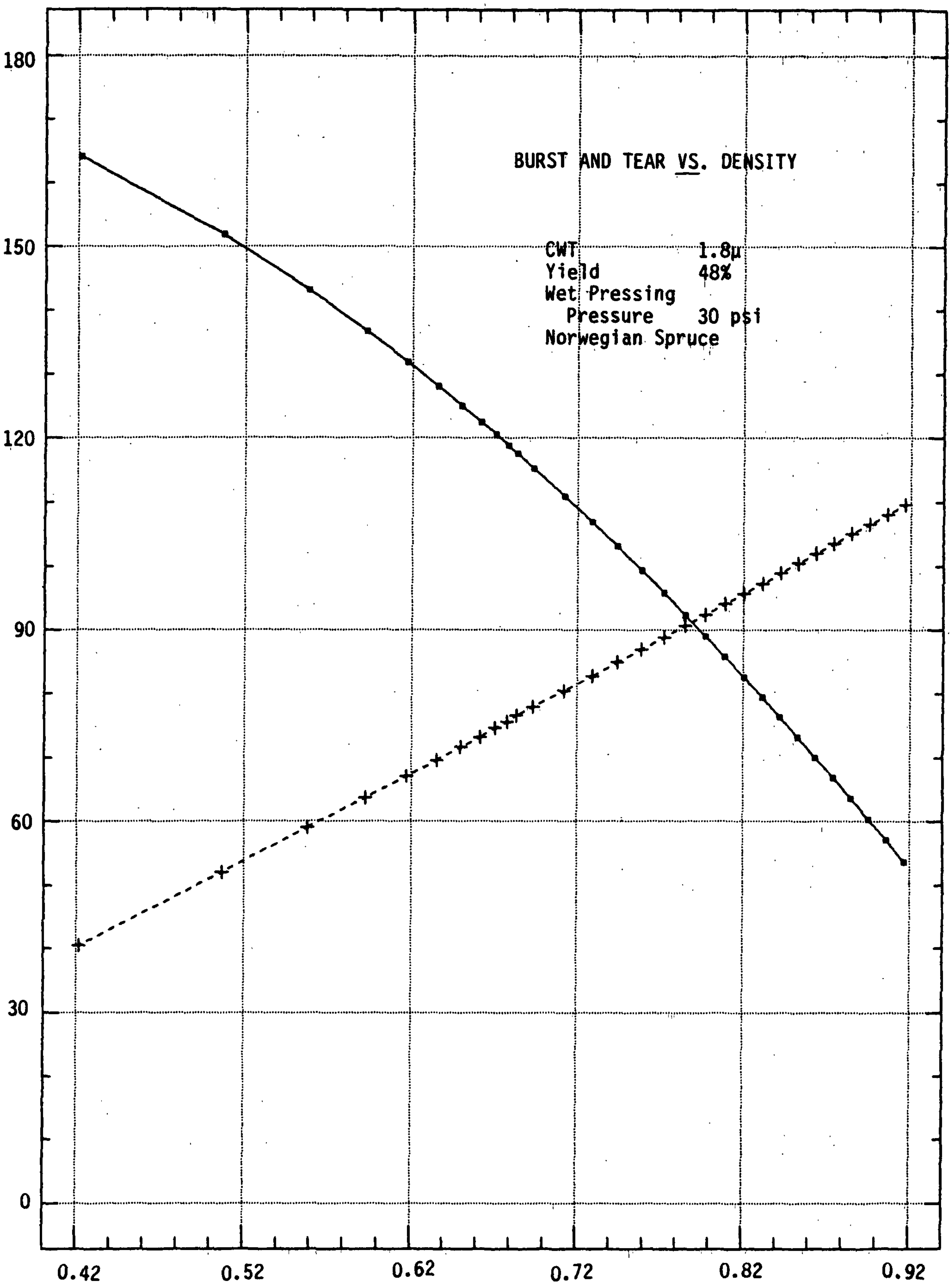
CWT 3.8µ Wet Pressing Pressure 30psi
Yield 60% Norwegian Spruce

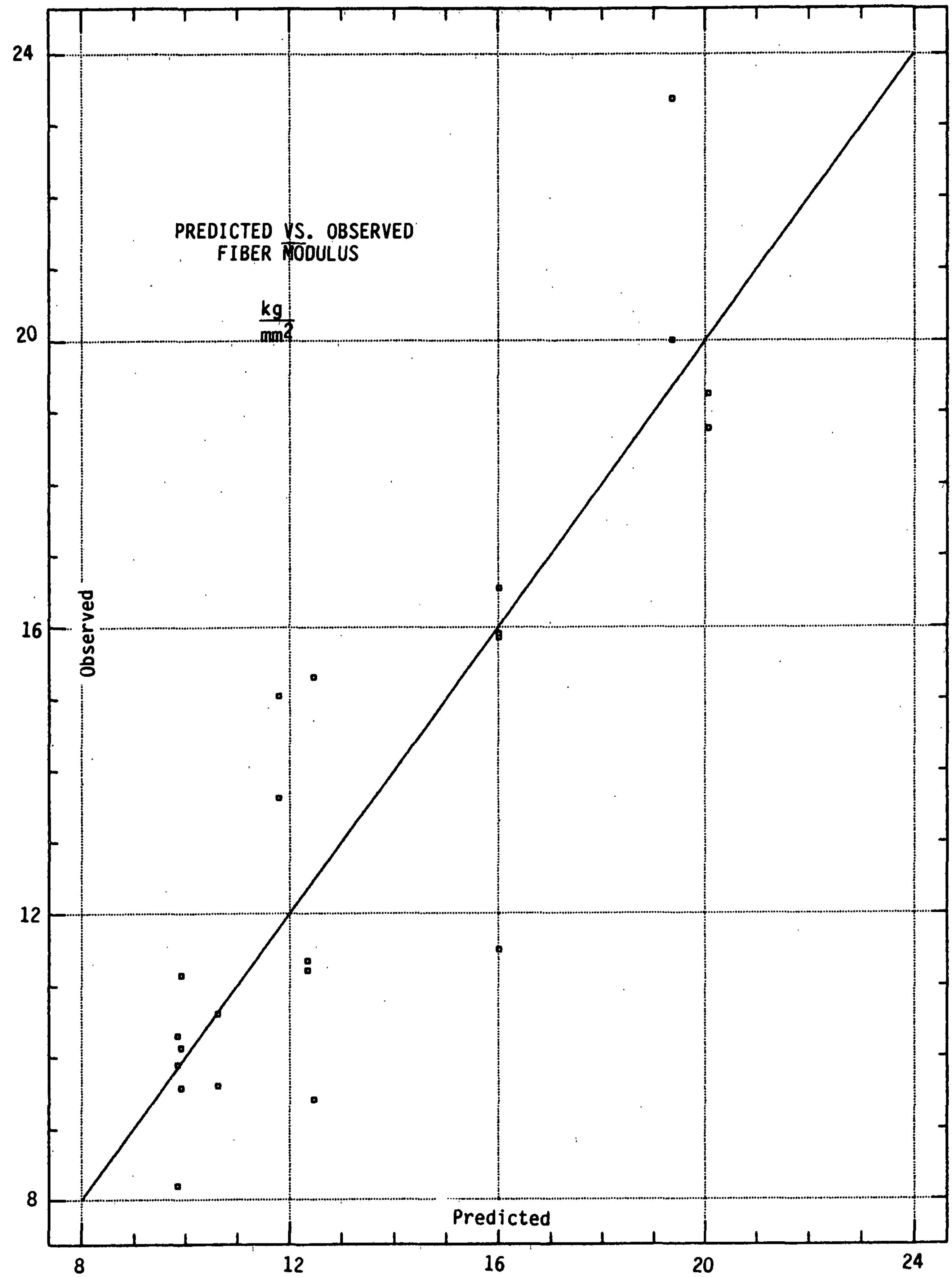


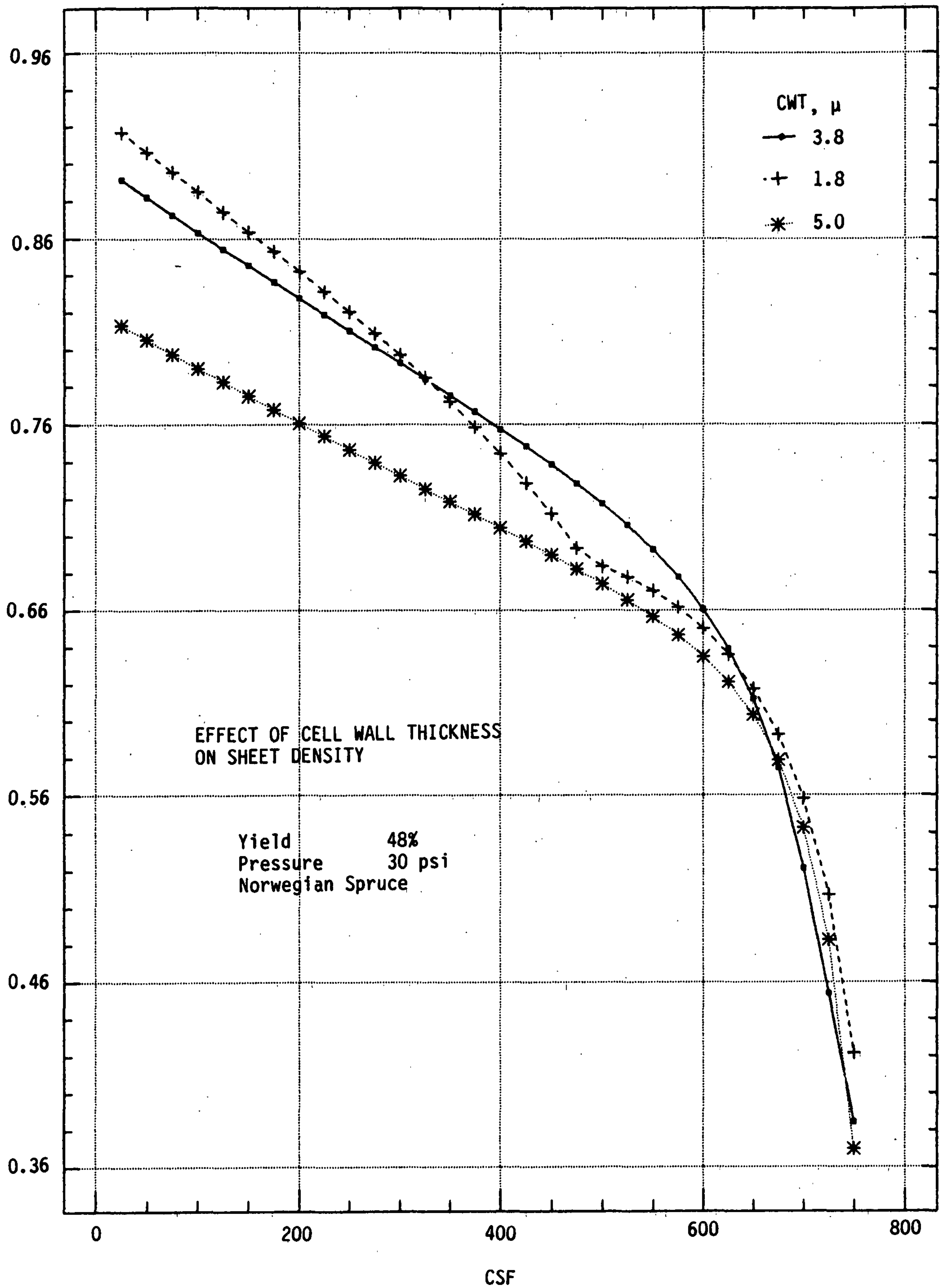


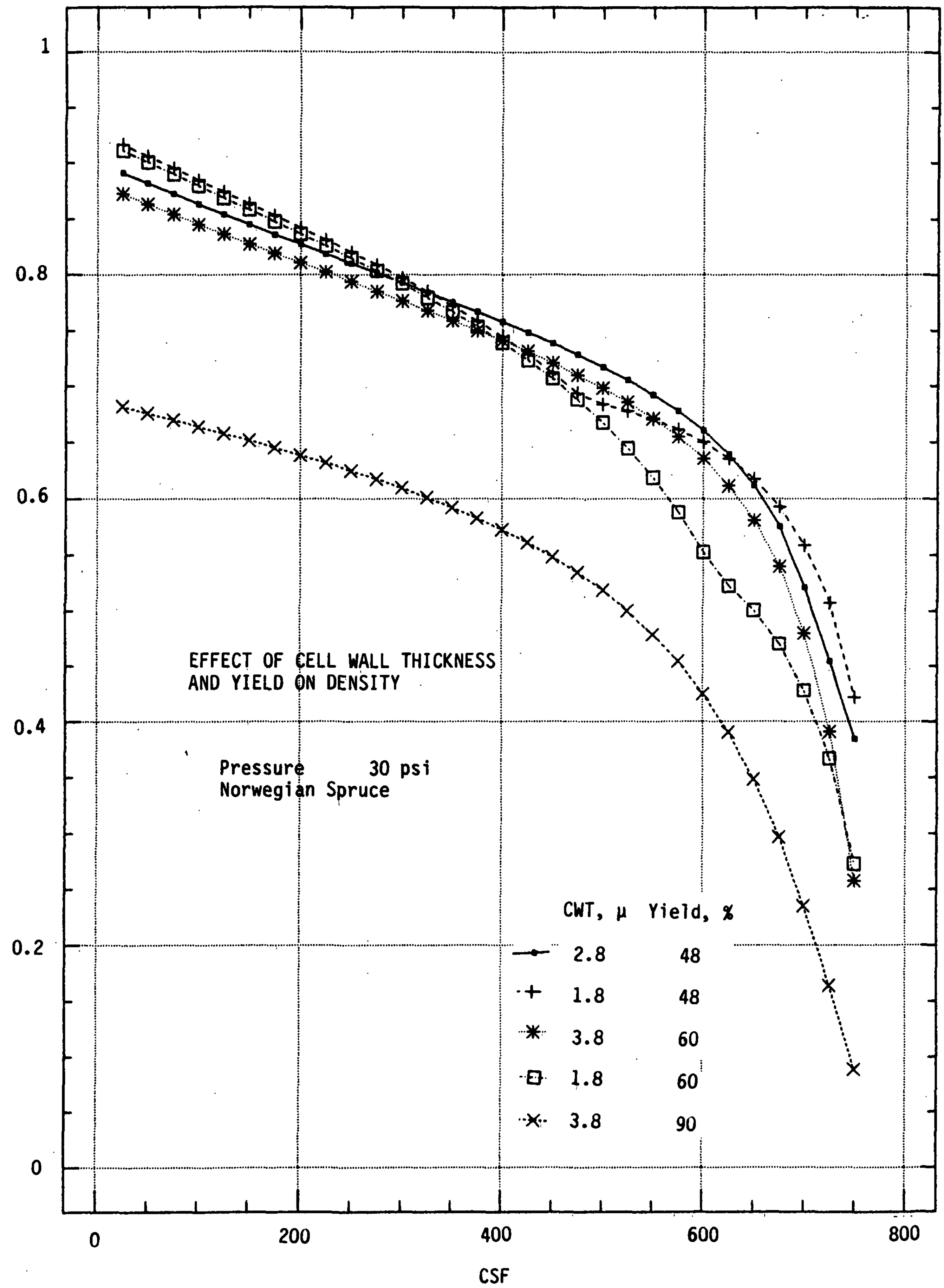
0.5
0.4
0.3
0.2
0.1
0
Predicted Density, g/cc
DENSITY VS. CSF PREDICTED
FOR 100% YIELD
Pressure 30 psi
CWT 3.8 μ
Canadian Standard Freeness, mL
0
200
400
600
800


EFFECT OF DENSITY ON SHEET STRENGTH
Pressure 30 psi
CWT 3.8 µ
Yield 48%
Norwegian Spruce
breaking length, Km
modulus dynes/cm2 x10-10
elongation, %
10
8
6
4
2
0
0.30
0.40
0.50
0.60
0.70
0.80
0.90
density, g/cm3

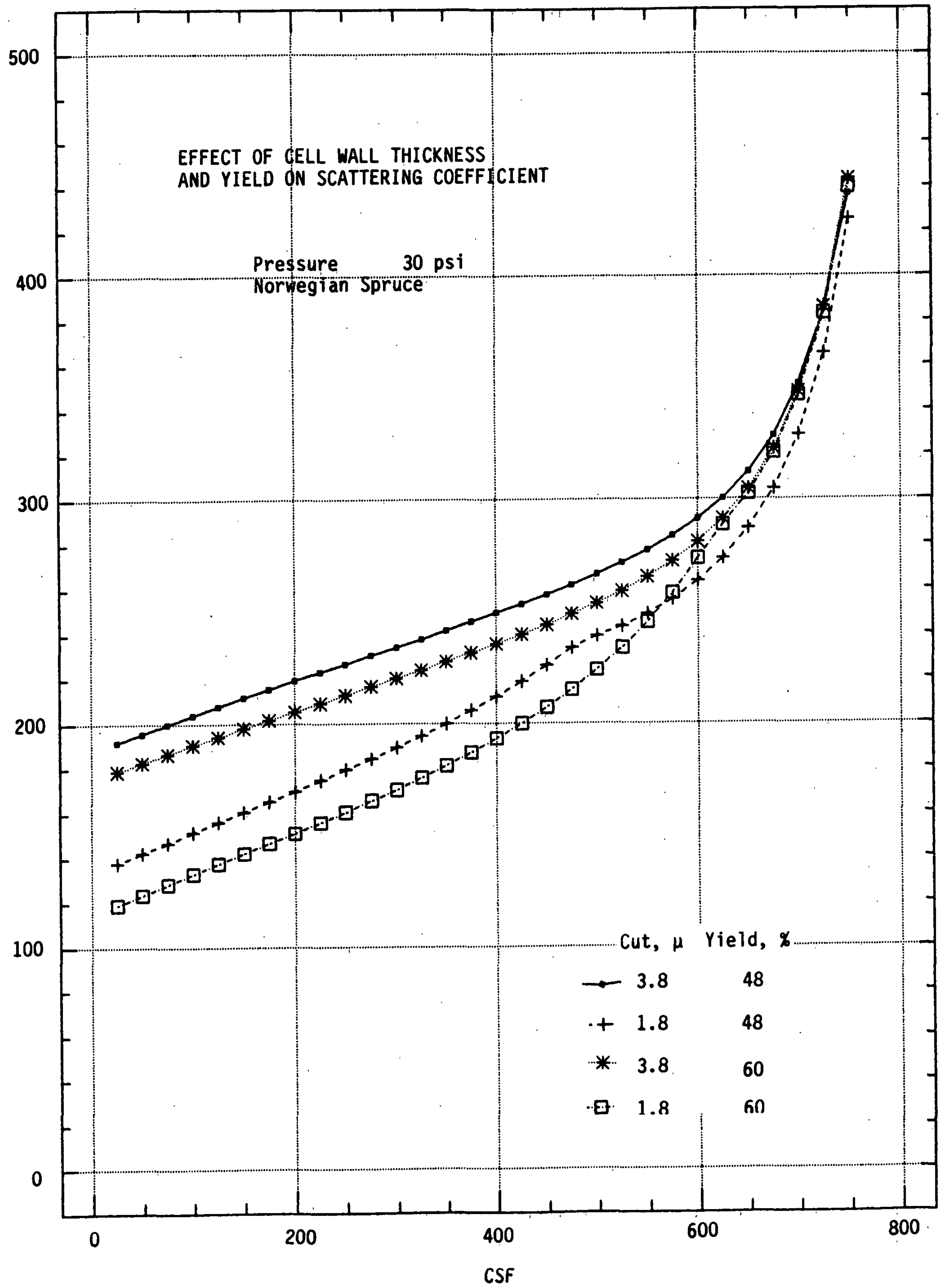

BURST AND TEAR VS. DENSITY
CWT 1.8μ
Yield 48%
Wet Pressing
Pressure 30 psi
Norwegian Spruce
180
150
120
90
60
30
0
0.42
0.52
0.62
0.72
0.82
0.92

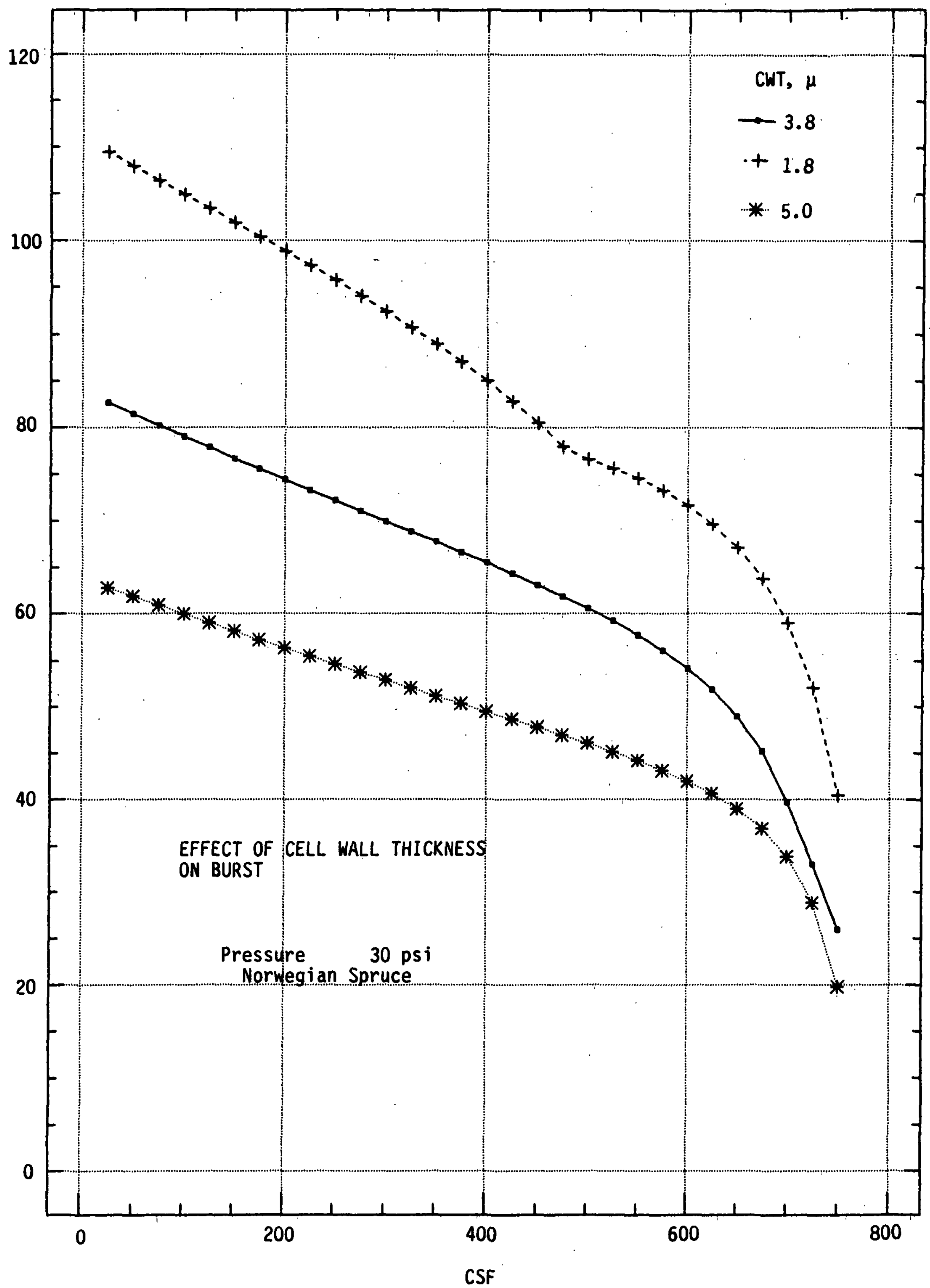

PREDICTED VS. OBSERVED
FIBER MODULUS
kg/mm2
Observed
Predicted
8
12
16
20
24
8
12
16
20
24

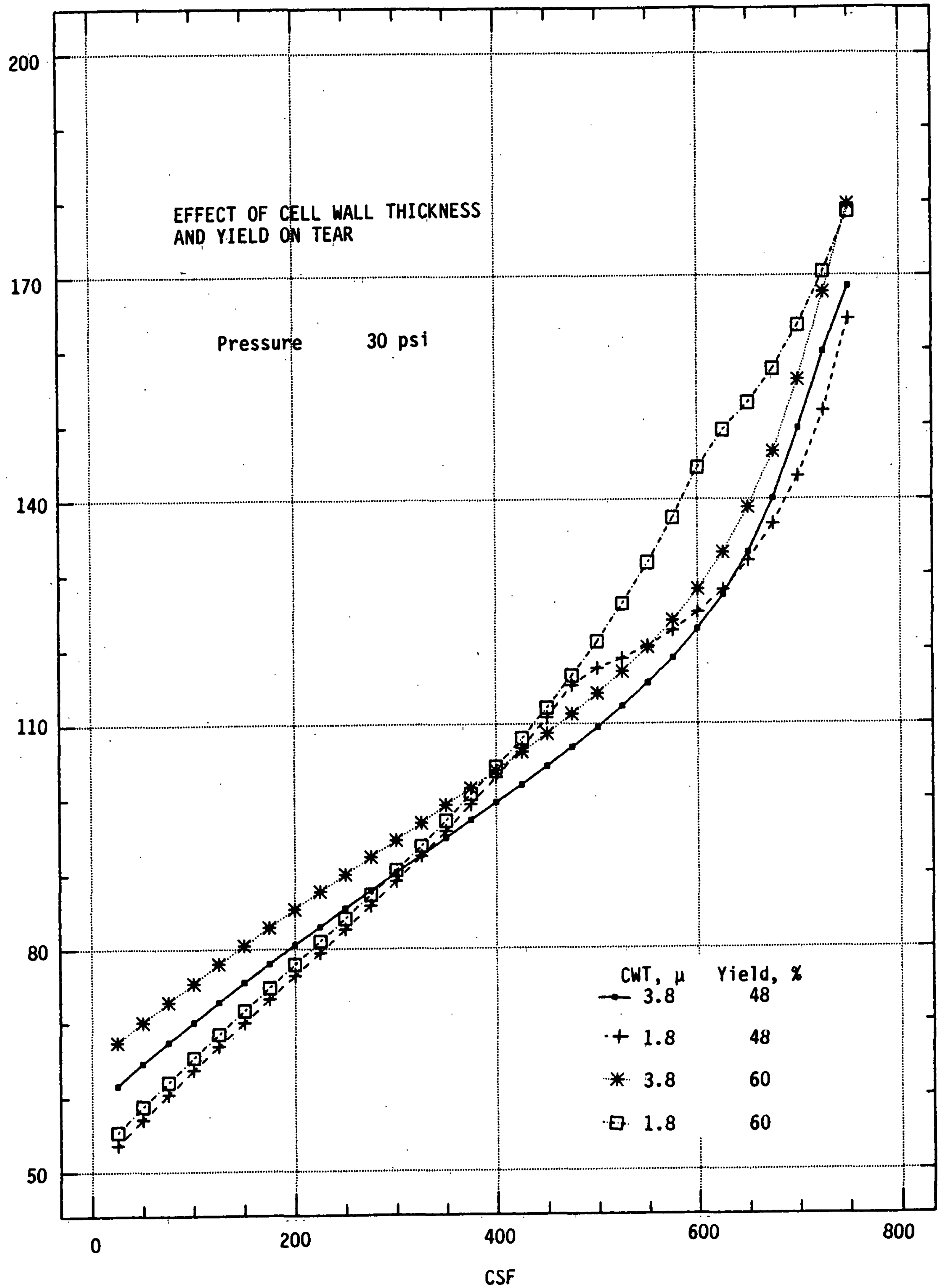

0.96
0.86
0.76
0.66
0.56
0.46
0.36
0
200
400
600
800
CSF
CWT, µ
3.8
1.8
5.0
EFFECT OF CELL WALL THICKNESS
ON SHEET DENSITY
Yield 48%
Pressure 30 psi
Norwegian Spruce

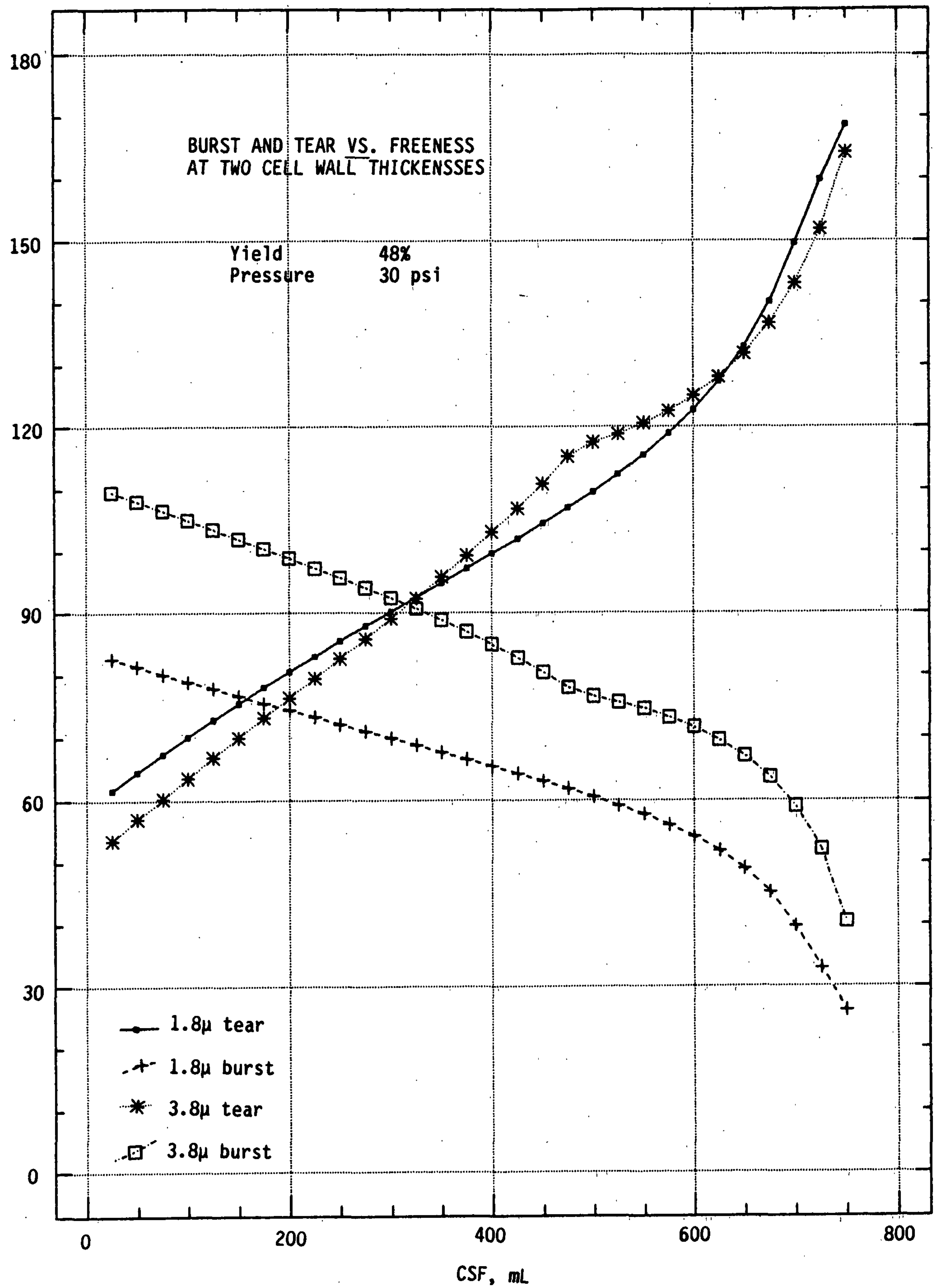


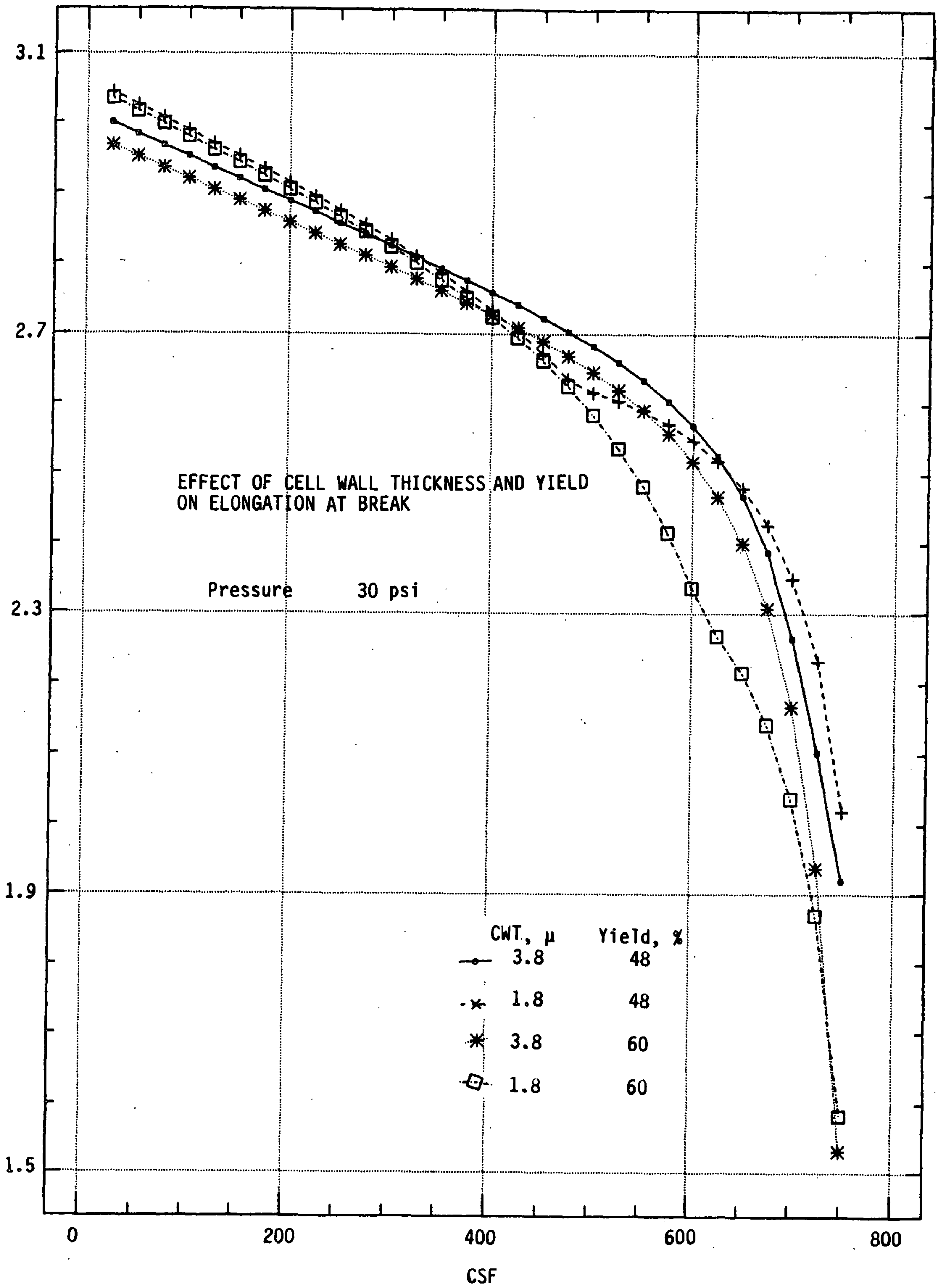
1
0.8
0.6
0.4
0.2
0
0
200
400
600
800
CSF
EFFECT OF CELL WALL THICKNESS
AND YIELD ON DENSITY
Pressure 30 psi
Norwegian Spruce
CWT, μ Yield, %
2.8 48
1.8 48
3.8 60
1.8 60
3.8 90


EFFECT OF CELL WALL THICKNESS
AND YIELD ON SCATTERING COEFFICIENT
Pressure 30 psi
Norwegian Spruce
500
400
300
200
100
0
0
200
400
600
800
CSF
Cut, μ Yield, %
3.8 48
1.8 48
3.8 60
1.8 60


CWT, μ
3.8
1.8
5.0
EFFECT OF CELL WALL THICKNESS
ON BURST
Pressure 30 psi
Norwegian Spruce
120
100
80
60
40
20
0
0
200
400
600
800
CSF

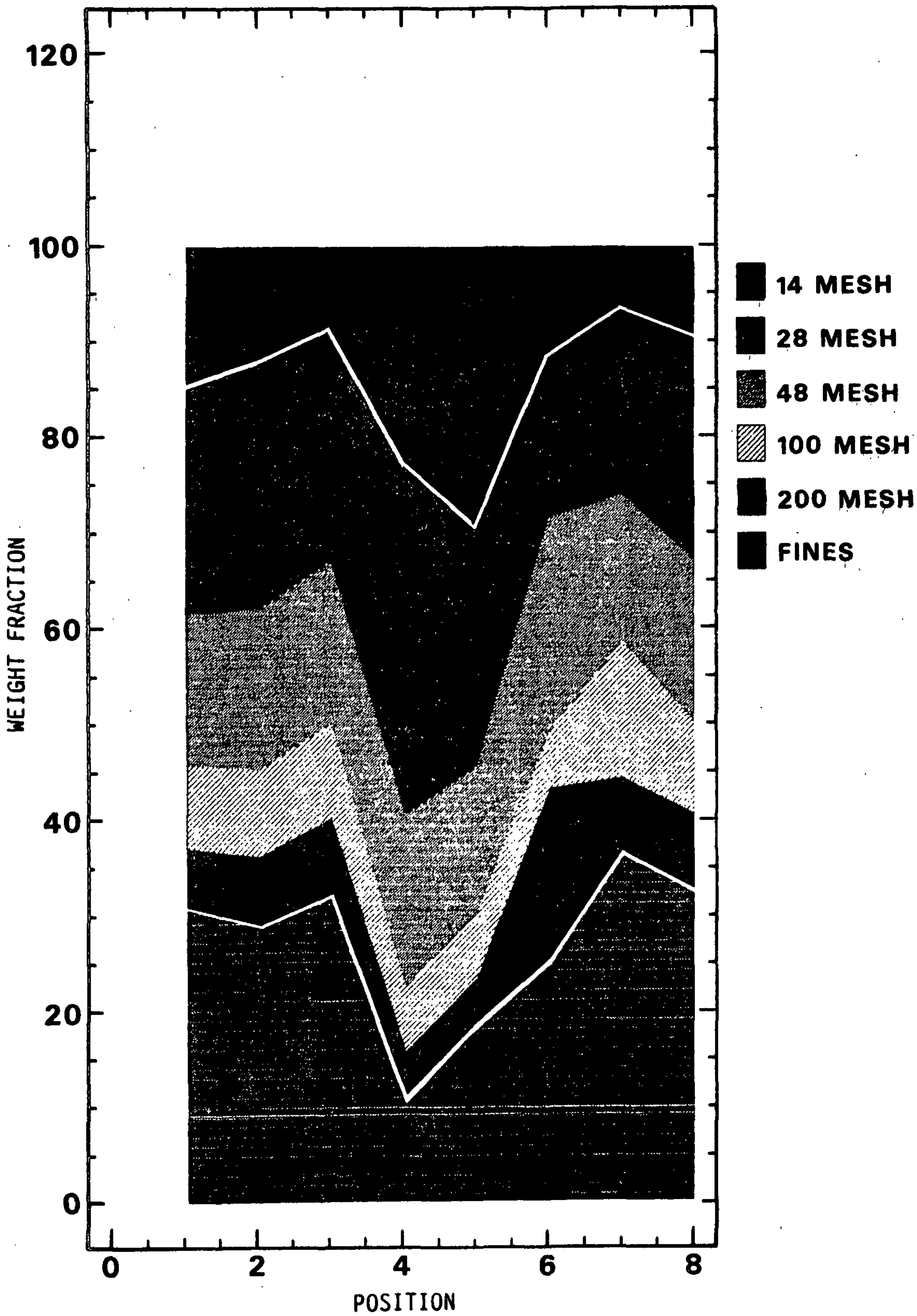

EFFECT OF CELL WALL THICKNESS
AND YIELD ON TEAR
Pressure 30 psi
200
170
140
110
80
50
0
200
400
600
800
CSF
CWT, μ Yield, %
3.8 48
1.8 48
3.8 60
1.8 60

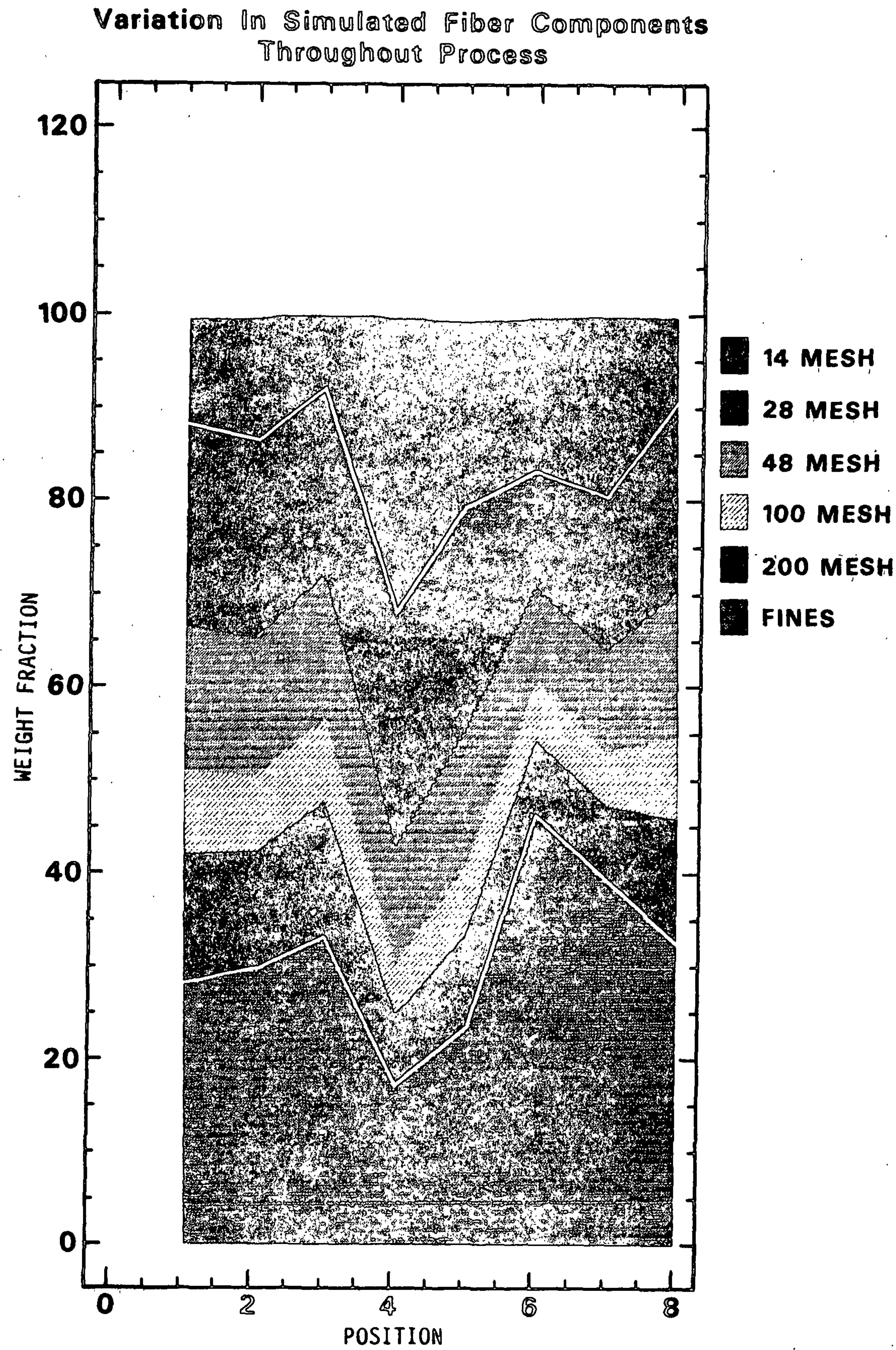

BURST AND TEAR VS. FREENESS
AT TWO CELL WALL THICKENSSES
Yield 48%
Pressure 30 psi
180
150
120
90
60
30
0
0
200
400
600
800
CSF, mL
1.8μ tear
1.8μ burst
3.8μ tear
3.8μ burst

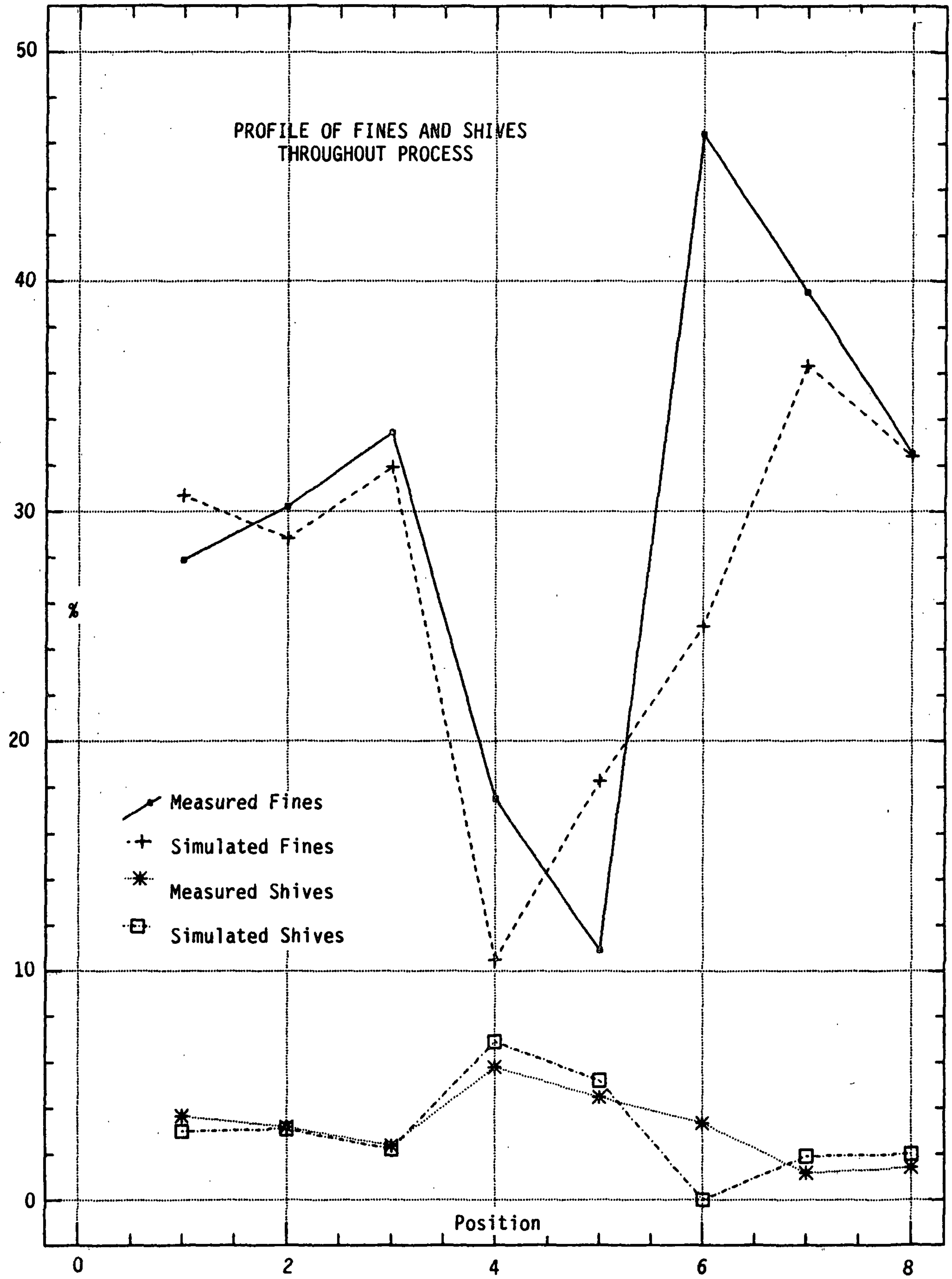

3.1
2.7
2.3
1.9
1.5
0
200
400
600
800
CSF
EFFECT OF CELL WALL THICKNESS AND YIELD
ON ELONGATION AT BREAK
Pressure 30 psi
CWT., μ Yield, %
3.8 48
1.8 48
3.8 60
1.8 60

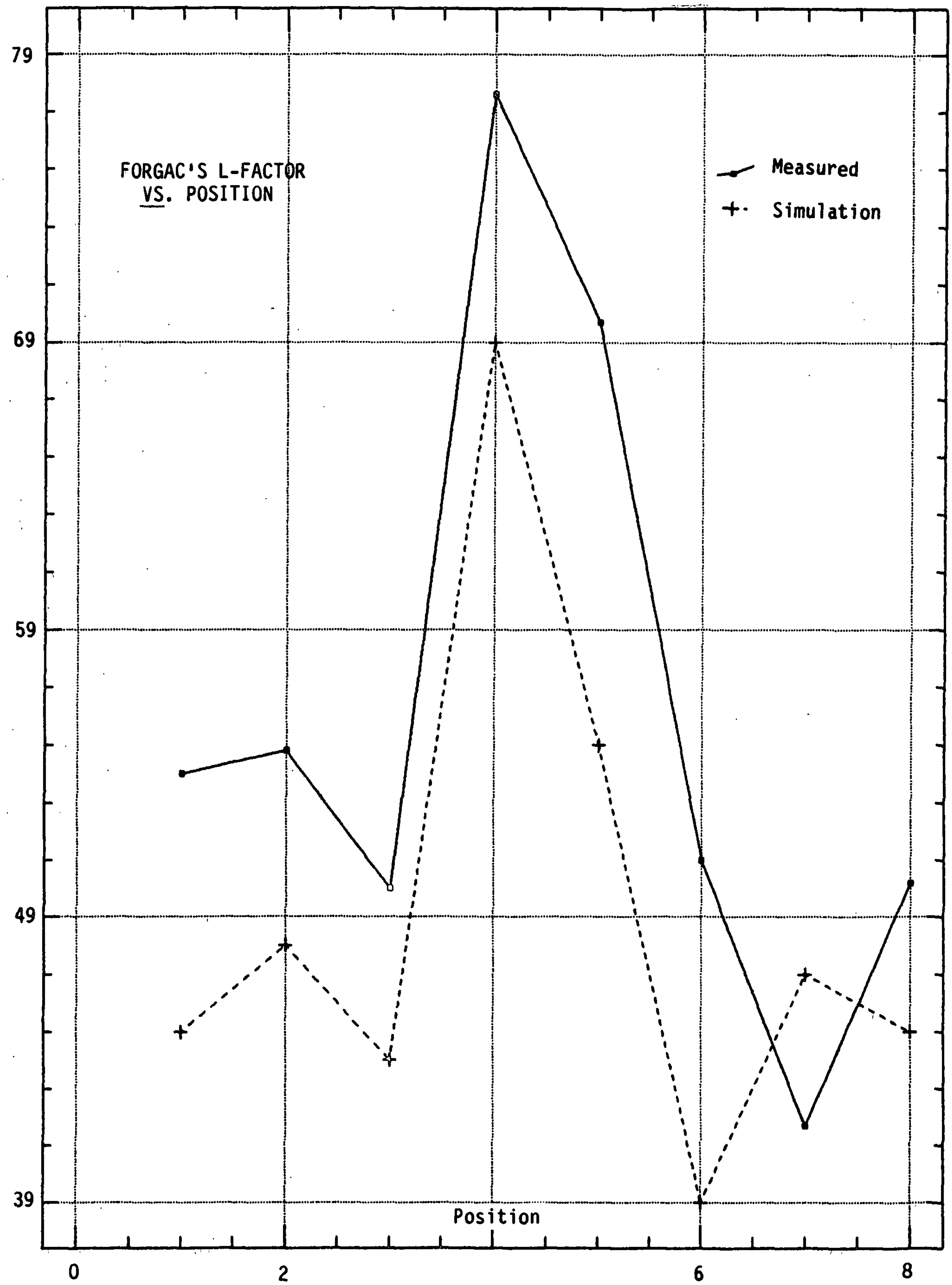
VARIATION IN MEASURED FIBER COMPONENTS THROUGHOUT PROCESS

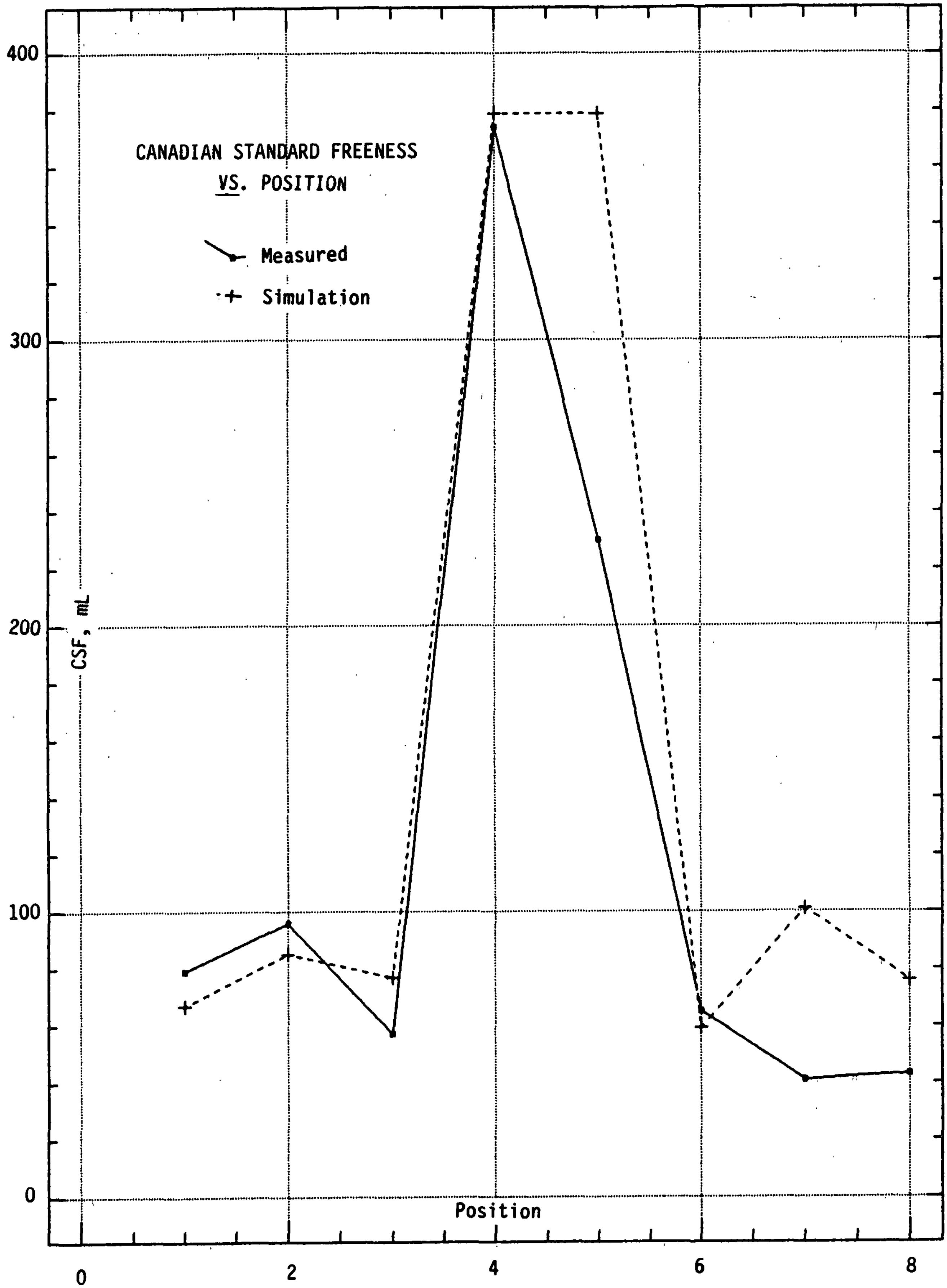
POSITION	
1	SECONDARY REFINER DISCHARGE
2	PRIMARY SCREEN FEED
3	PRIMARY SCREEN ACCEPTS
4	PRIMARY SCREEN REJECTS
5	SECONDARY SCREEN ACCEPTS
6	REJECT REFINER DISCHARGE
7	PRIMARY REJECT CLEANER ACCEPTS
8	THICKENER DISCHARGE

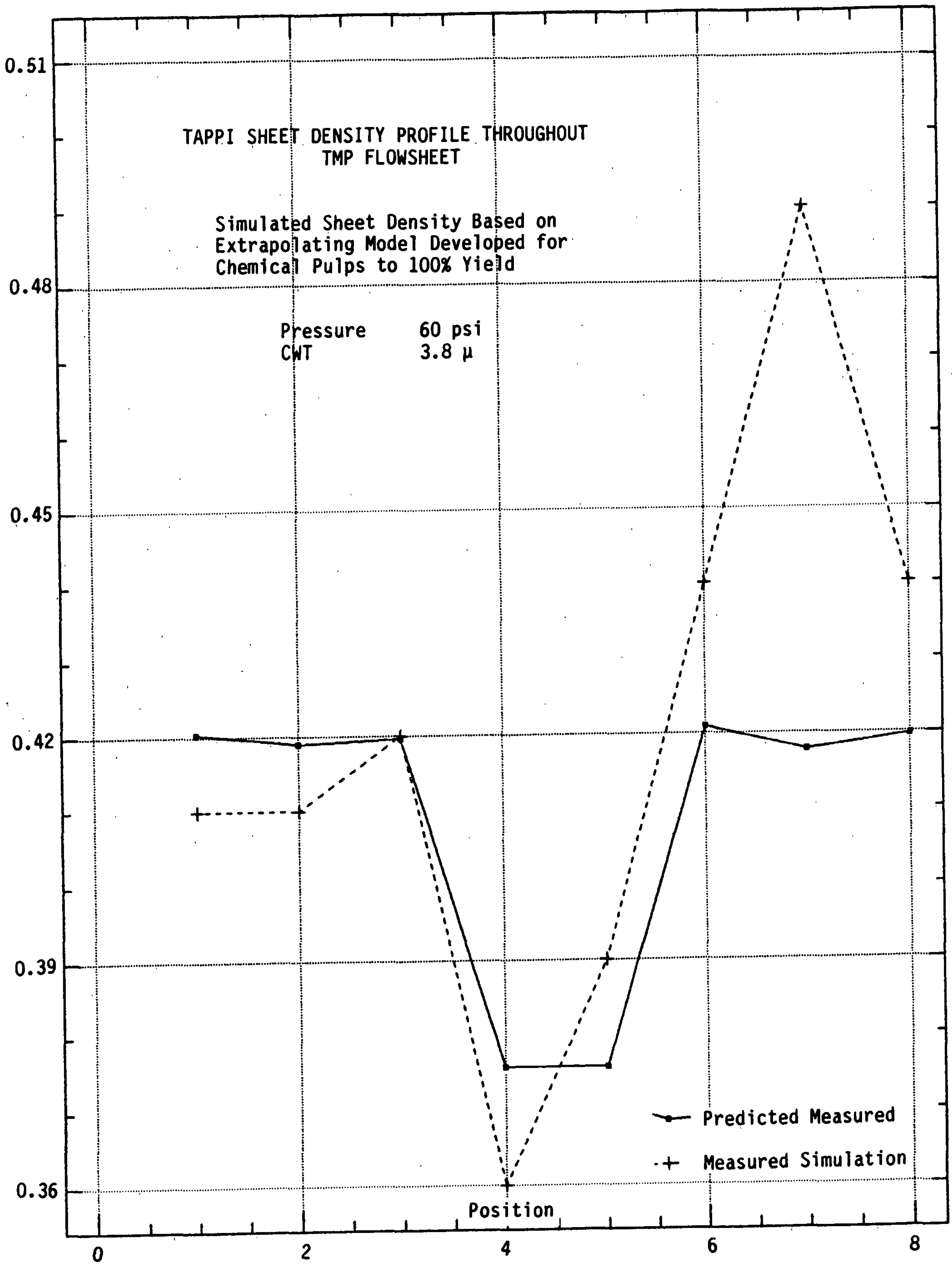

120
100
80
60
40
20
0
WEIGHT FRACTION
0
2
4
6
8
POSITION
14 MESH
28 MESH
48 MESH
100 MESH
200 MESH
FINES

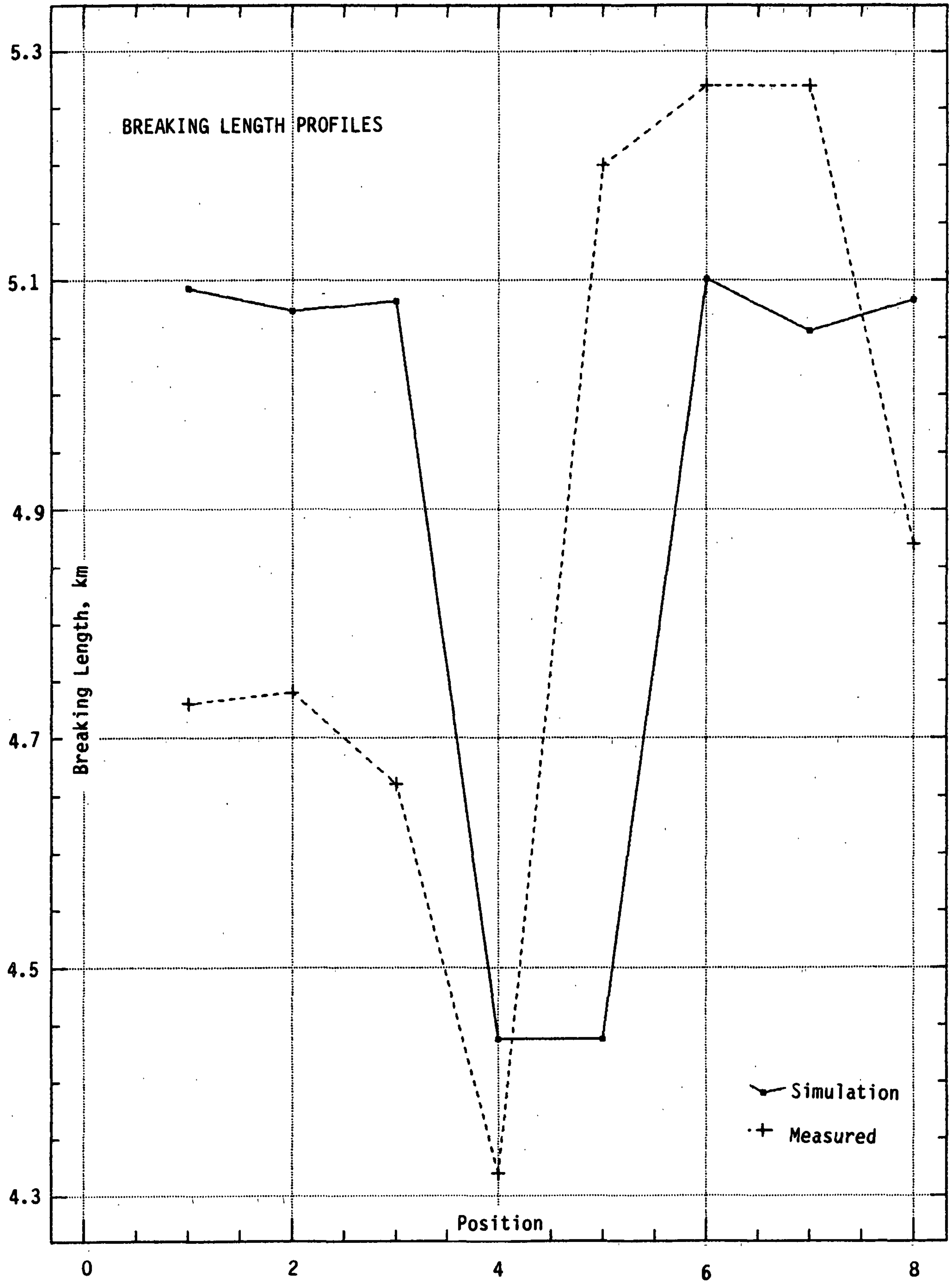

Variation In Simulated Fiber Components
Throughout Process
120
100
80
60
40
20
0
WEIGHT FRACTION
0
2
4
6
8
POSITION
14 MESH
28 MESH
48 MESH
100 MESH
200 MESH
FINES

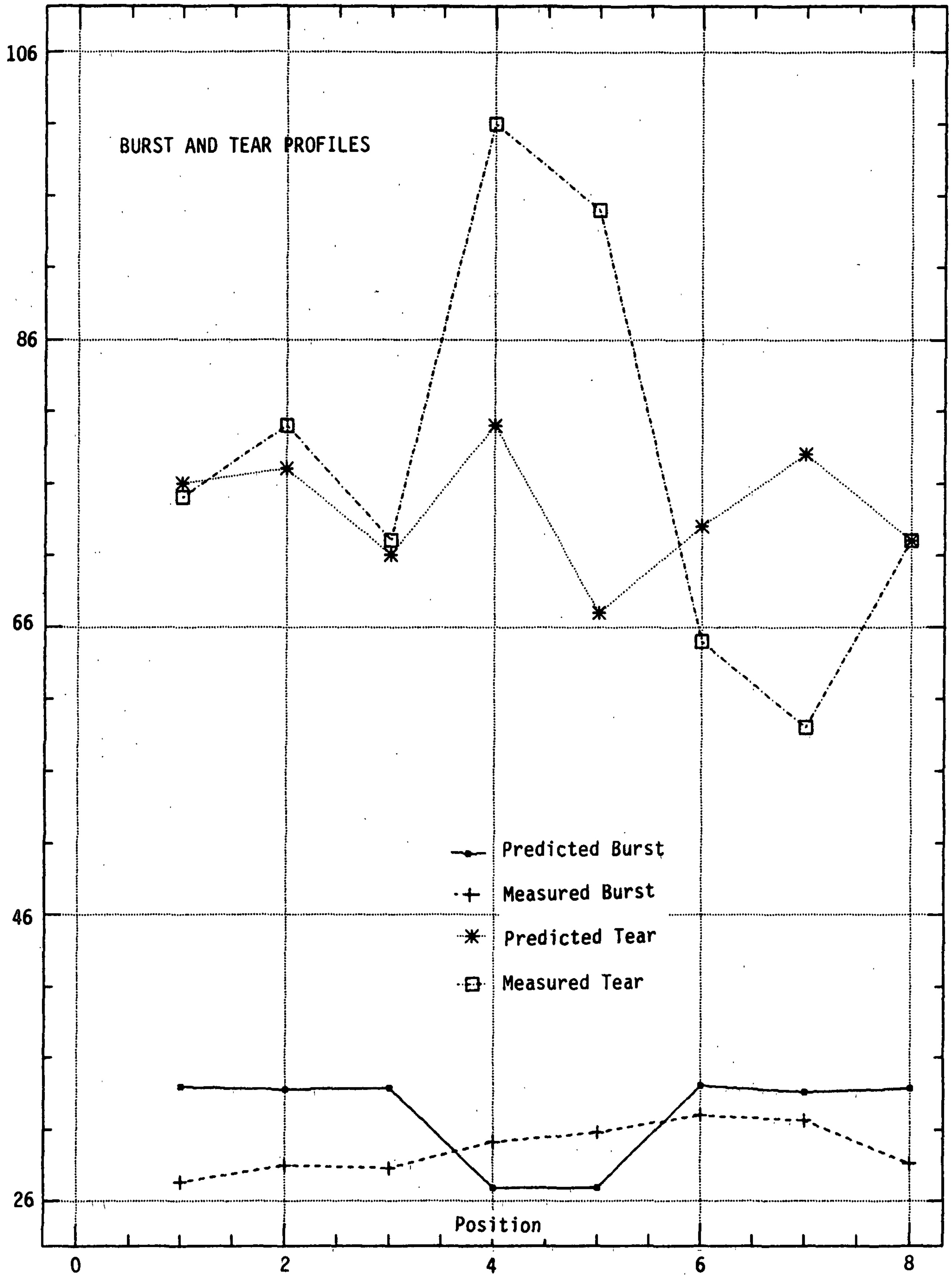

PROFILE OF FINES AND SHIVES
THROUGHOUT PROCESS
50
40
30
20
10
0
%
Measured Fines
Simulated Fines
Measured Shives
Simulated Shives
Position
0
2
4
6
8


FORGAC'S L-FACTOR
VS. POSITION
Measured
Simulation
79
69
59
49
39
Position
0
2
6
8

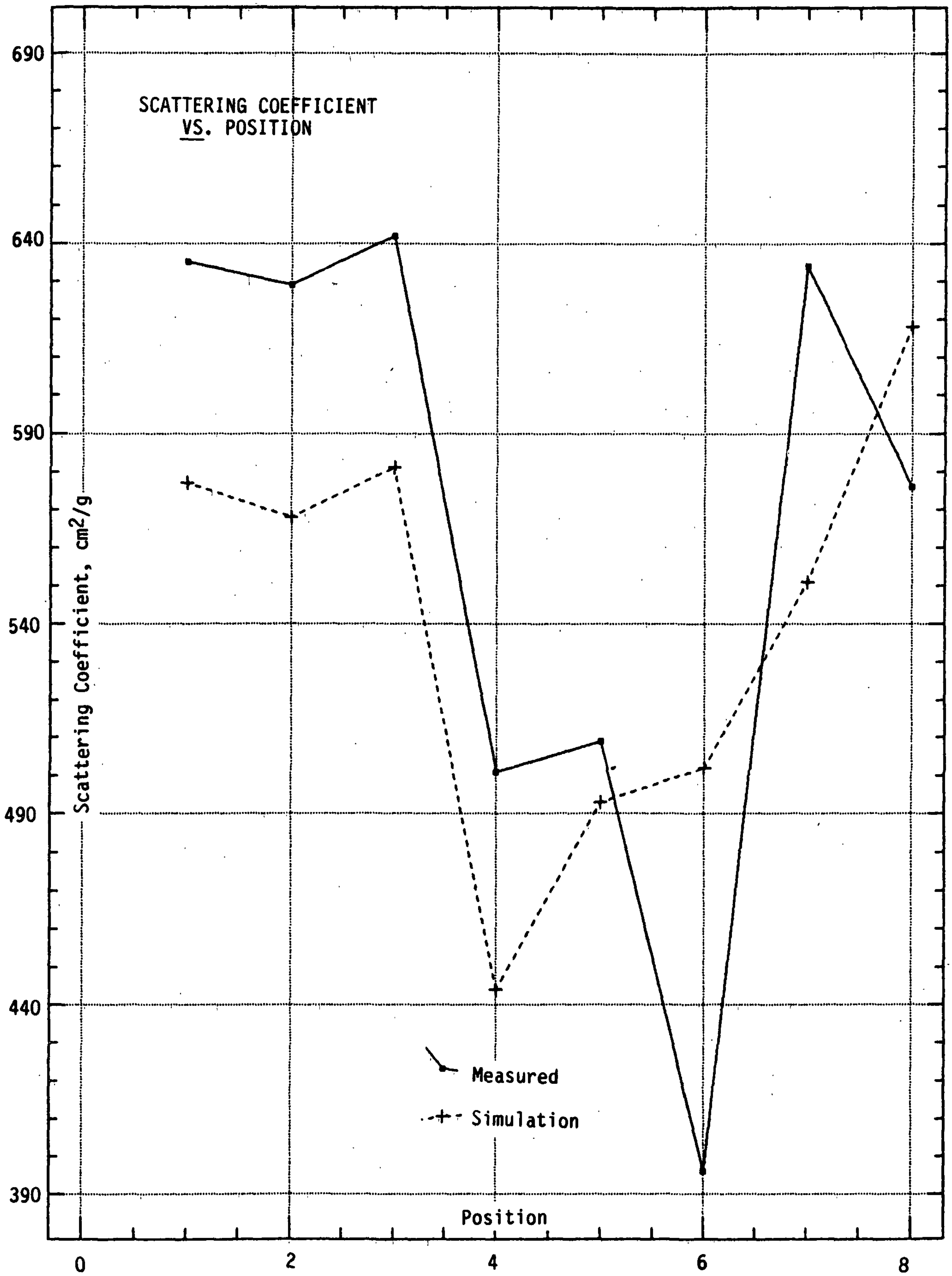

CANADIAN STANDARD FREENESS
VS. POSITION
Measured
Simulation
CSF, mL
400
300
200
100
0
Position
0
2
4
6
8

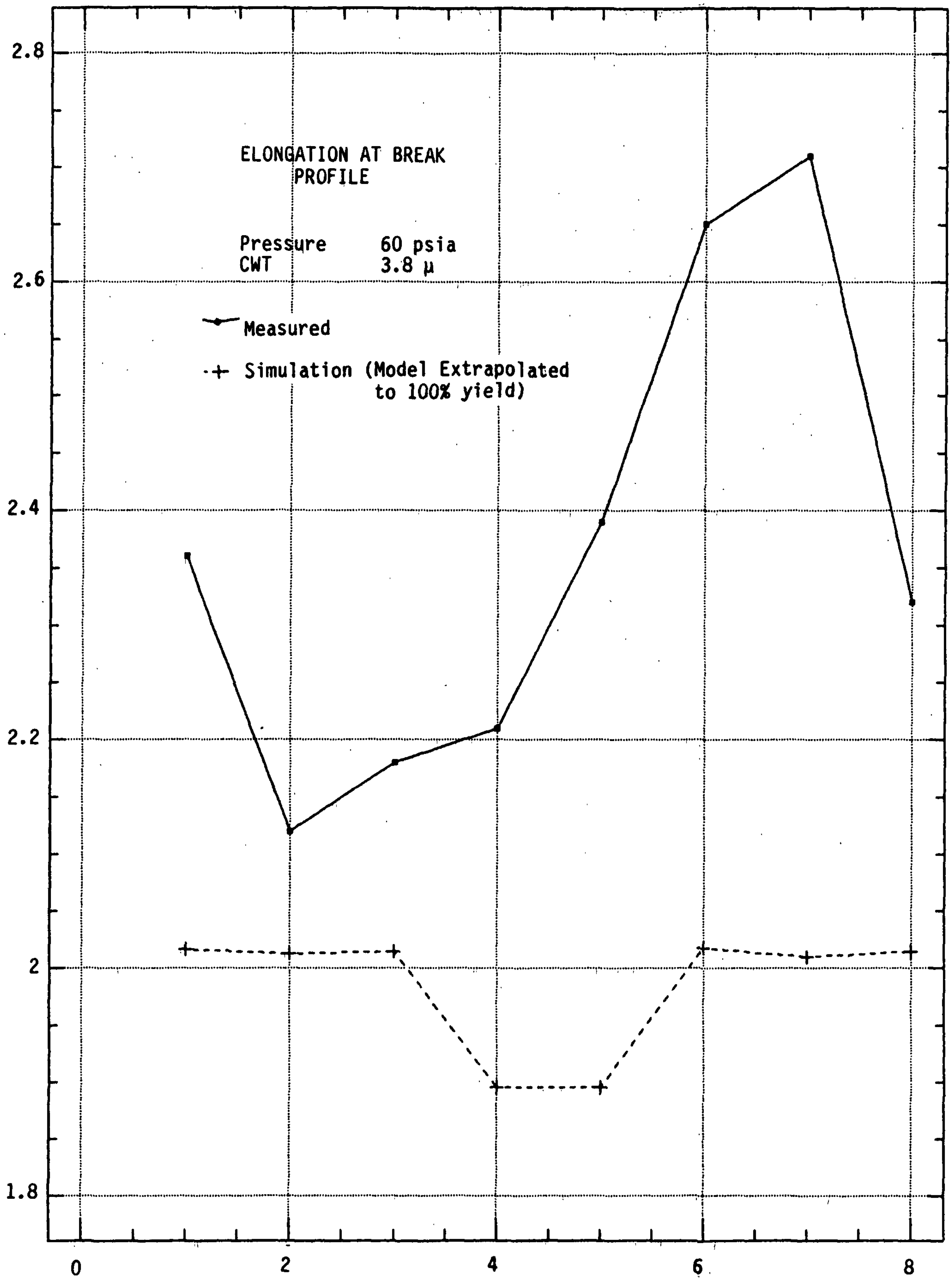

TAPPI SHEET DENSITY PROFILE THROUGHOUT
TMP FLOWSHEET
Simulated Sheet Density Based on
Extrapolating Model Developed for
Chemical Pulps to 100% Yield
Pressure 60 psi
CWT 3.8 μ
0.51
0.48
0.45
0.42
0.39
0.36
Position
0
2
4
6
8
Predicted Measured
Measured Simulation


BREAKING LENGTH PROFILES
5.3
5.1
4.9
4.7
4.5
4.3
Breaking Length, km
Position
0
2
4
6
8
Simulation
Measured



BURST AND TEAR PROFILES
106
86
66
46
26
Predicted Burst
Measured Burst
Predicted Tear
Measured Tear
Position
0
2
4
6
8


690
640
590
540
490
440
390
SCATTERING COEFFICIENT
VS. POSITION
Scattering Coefficient, cm^2/g
Measured
Simulation
Position
0
2
4
6
8


ELONGATION AT BREAK
PROFILE
Pressure 60 psia
CWT 3.8 μ
Measured
Simulation (Model Extrapolated to 100% yield)
2.8
2.6
2.4
2.2
2
1.8
0
2
4
6
8

IMPLEMENTATION

- NOW UNDERWAY
- MODULES AFFECTED

  WOOD BLOCK (GENERATE STREAMS)
  DIGESTER (YIELD AND KAPPA)
  REFINERS (HYRFN1)
  SCREENS (HYFRAC)
  MIXING (STOMIX)
  BLEACH MODULES

- PAPER MACHINE

  NEW MODULES

  * WET END MODULE

    ORIENTATION
    WET STRETCH
    WET PRESSING
    WET END CHEMISTRY
    FORMATION

  * DRYING AND CALENDERING

    DRAINAGE
      - USE HYFRAC OPTIONS

DEVELOPMENT ISSUES

OPTIMIZER

DEVELOPMENT

- LICENSE PACKAGE FROM DESIGN PRODUCTIVITY CENTER (DPC)
- MODIFY FOR USE WITH MAPPS (MAINFRAME AND PC VERSIONS)
- TEST AND DETERMINE BEST ROUTINES
- DEVELOP IMPROVED INTERFACE

MARKETING

- DETERMINE PRICE FOR INTERFACE
- LICENSE INTERFACE AS SEPARATE PACKAGE TO RUN OPTIMIZER WITH MAPPS
- WORK OUT DPC LICENSING ARRANGEMENTS

OPTIMIZER

MAINTENANCE AND DEVELOPMENT

- MAPPS RESPONSIBLE FOR INTERFACE
- DPC RESPONSIBLE FOR OPTIMIZATION CODE

CUSTOMER RELATIONS

- DEFINE MAPPS AND DPC ROLES
- DETERMINE RESOURCES NEEDED
- WORK OUT ARRANGEMENTS WITH DPC

DYNAMIC SIMULATION

STUDENT WORK - BOB ALOISI

NEW MODULES
- EXECUTIVE
- FIRST ORDER LAG
- DEAD TIME
- CONTROLLERS

TESTING, EVALUATION

COMPLETION BY SPRING 1989