SLIDE MATERIAL

To The

PAPER PROPERTIES AND USES

PROJECT ADVISORY COMMITTEE

March 21, 1990
Institute of Paper Science and Technology
Atlanta, Georgia

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TABLE OF CONTENTS

ON-LINE MEASUREMENT OF PAPER

SLIDE MATERIAL

FOR

PROJECT 3332

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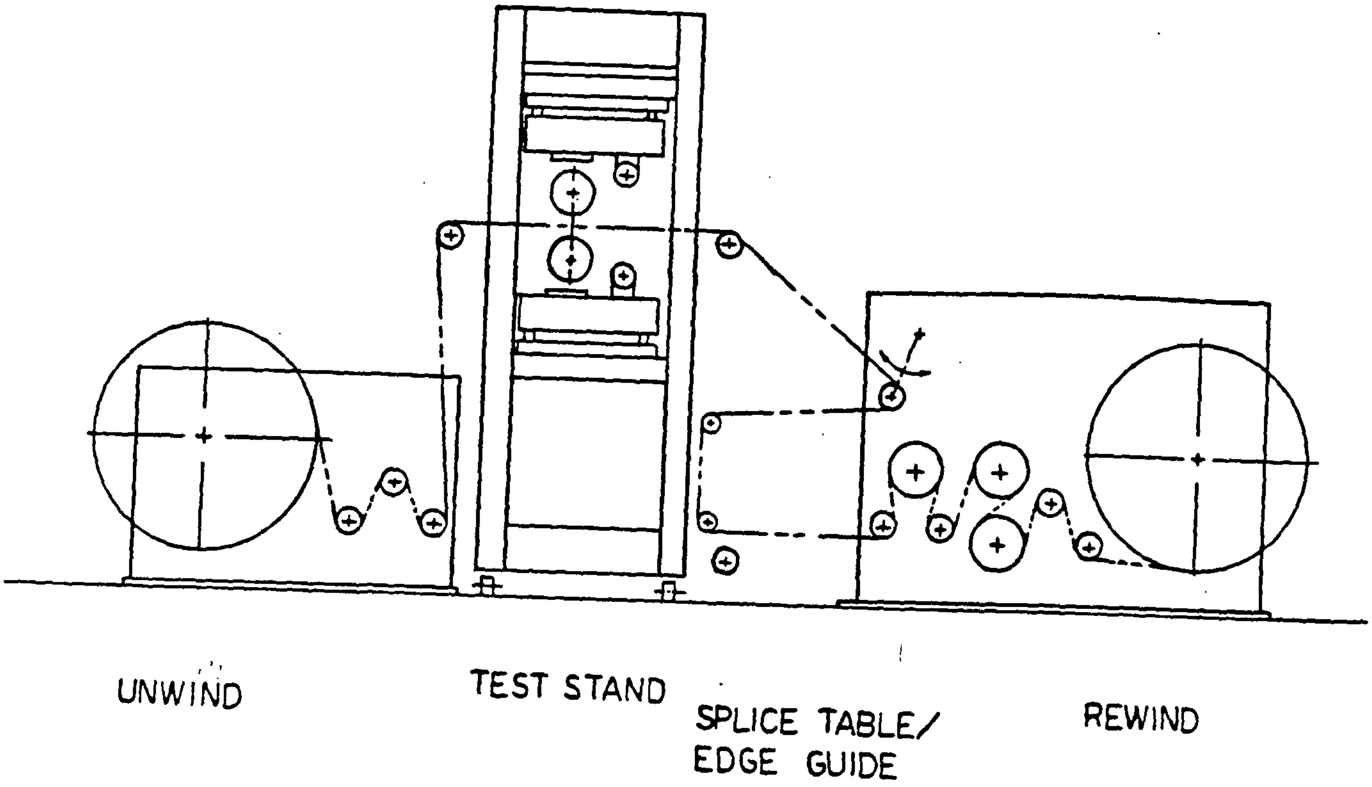
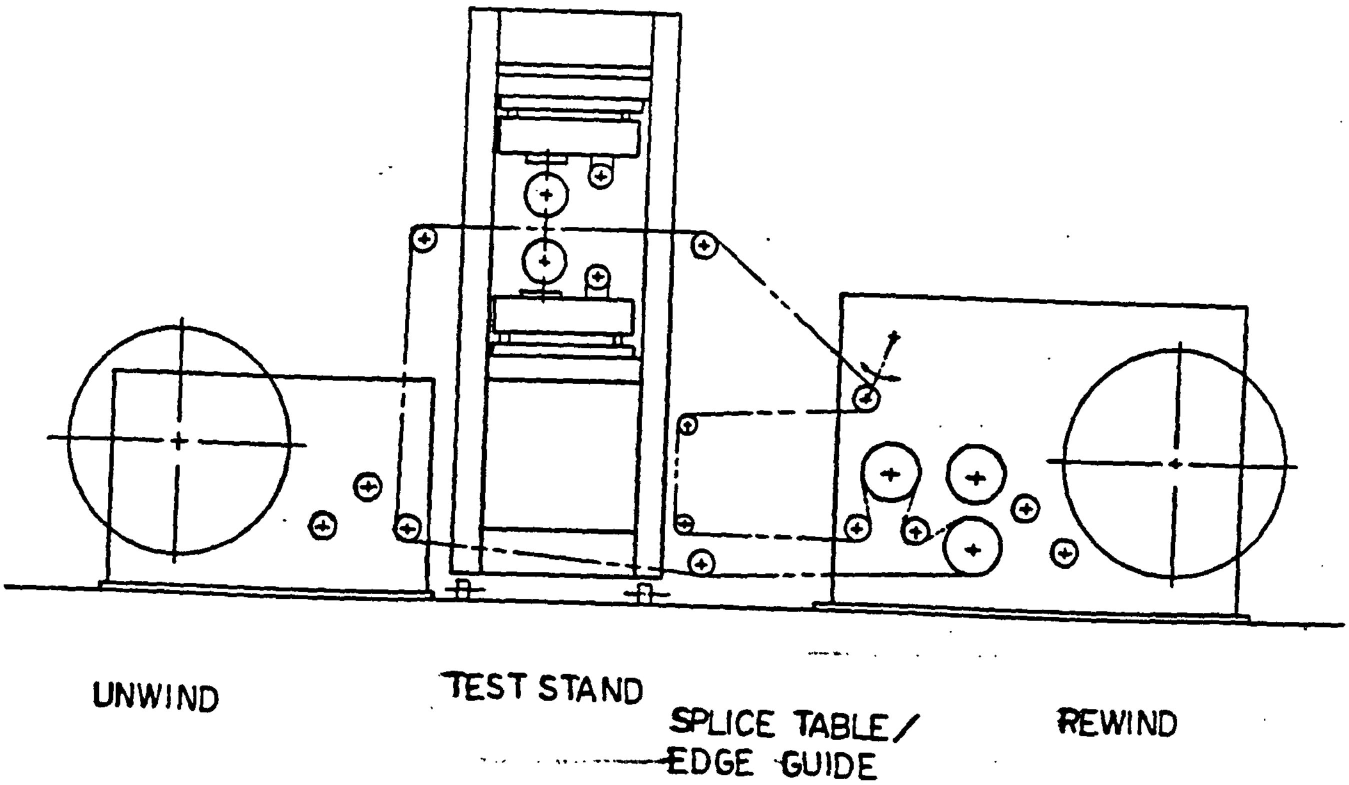
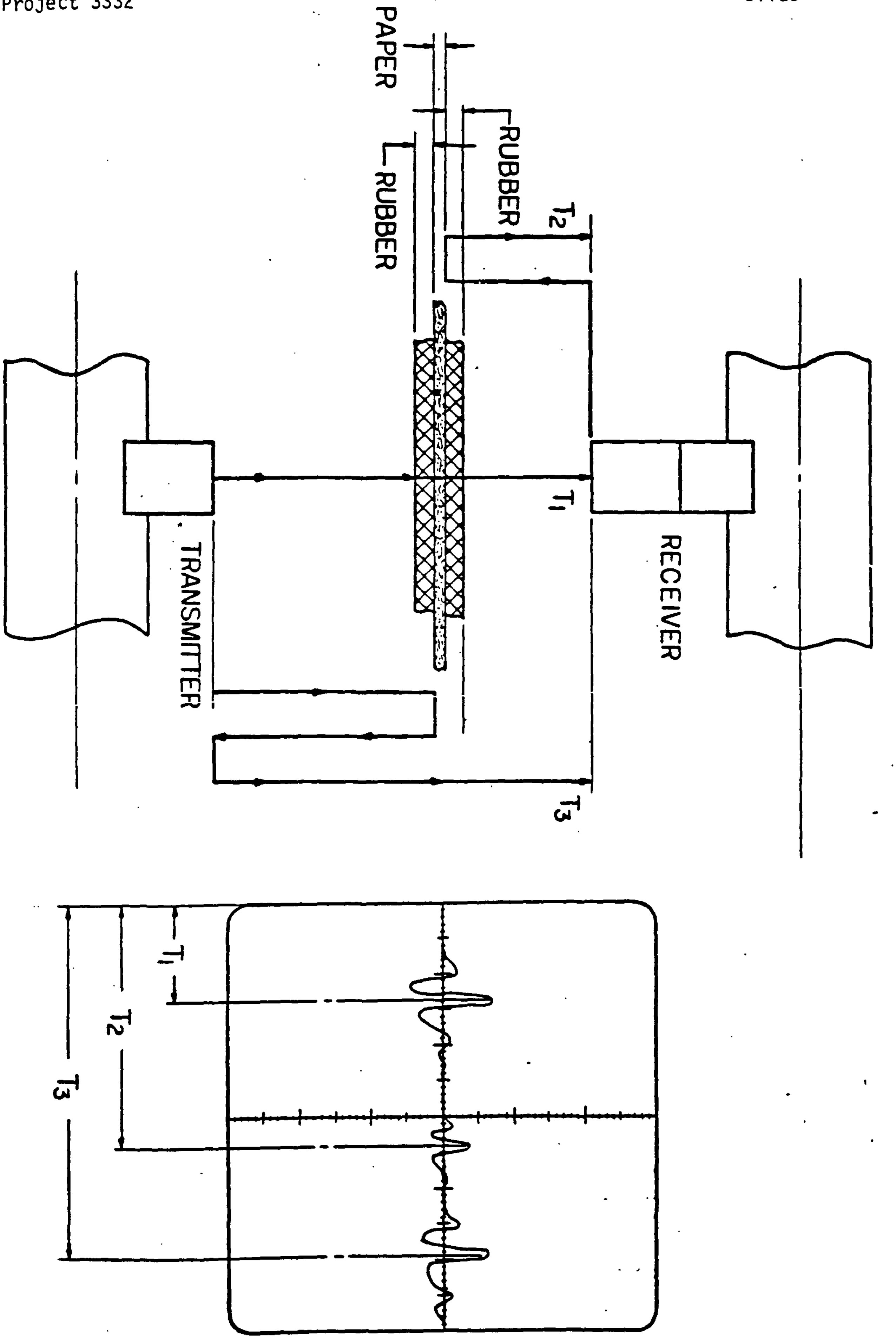
March 21, 1990

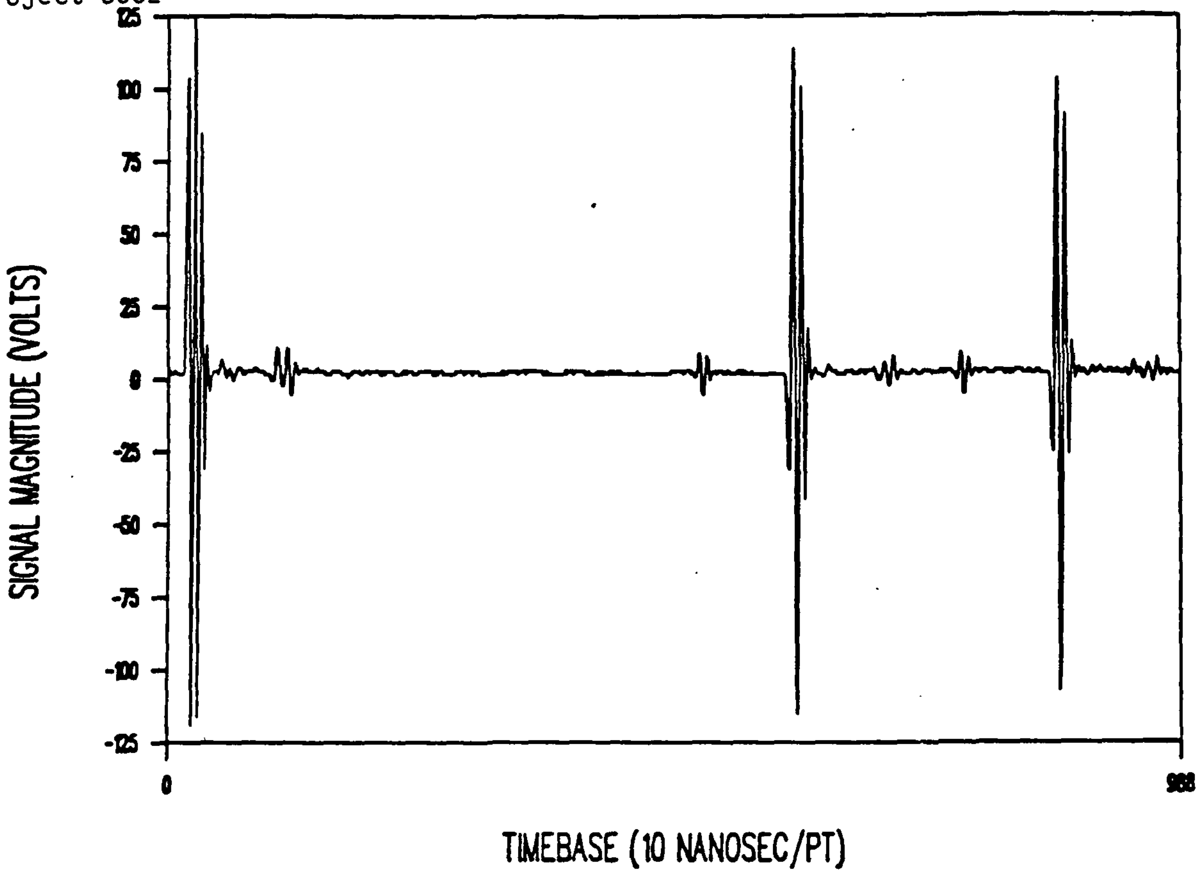
REEL-TO-REEL PATH

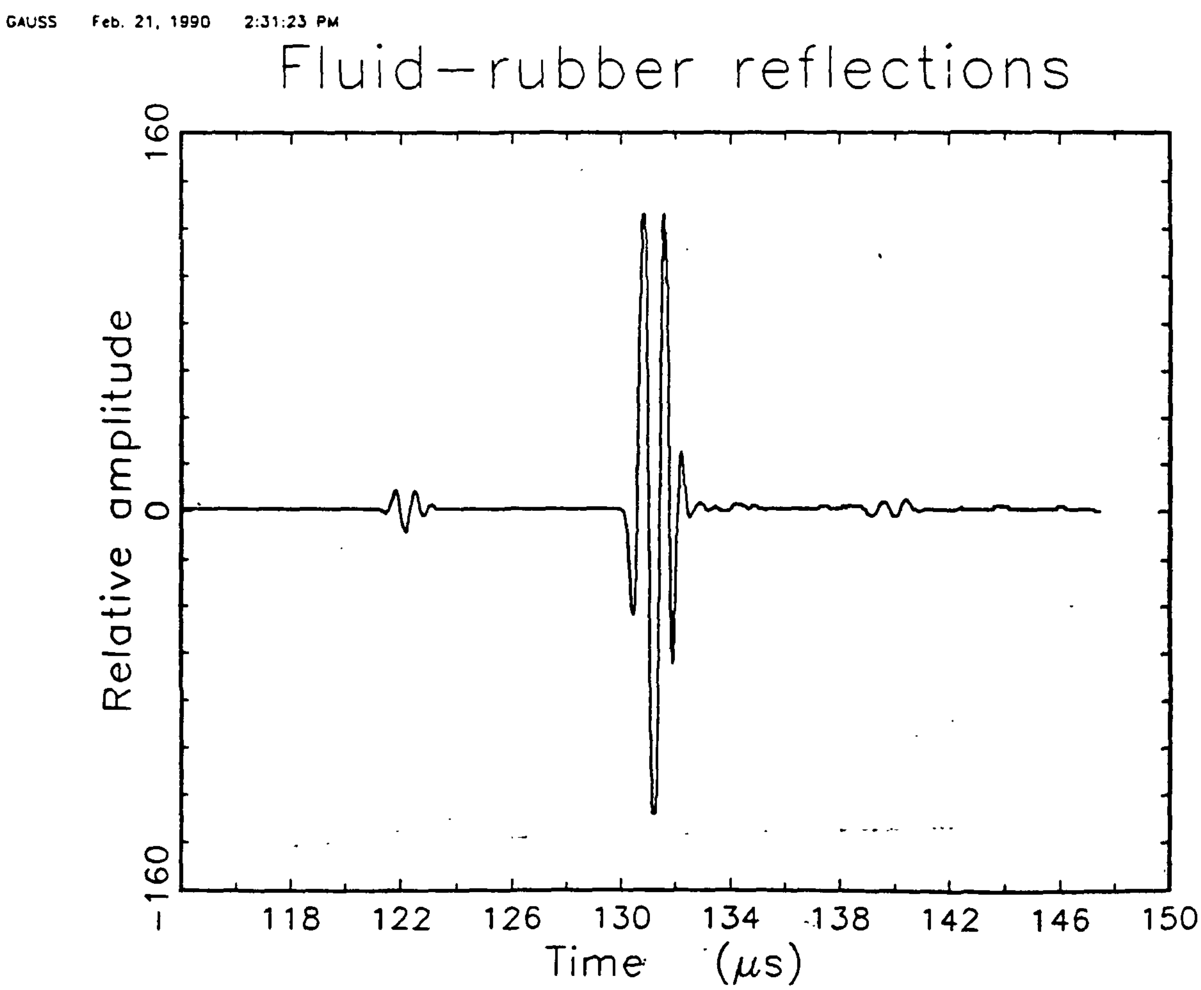


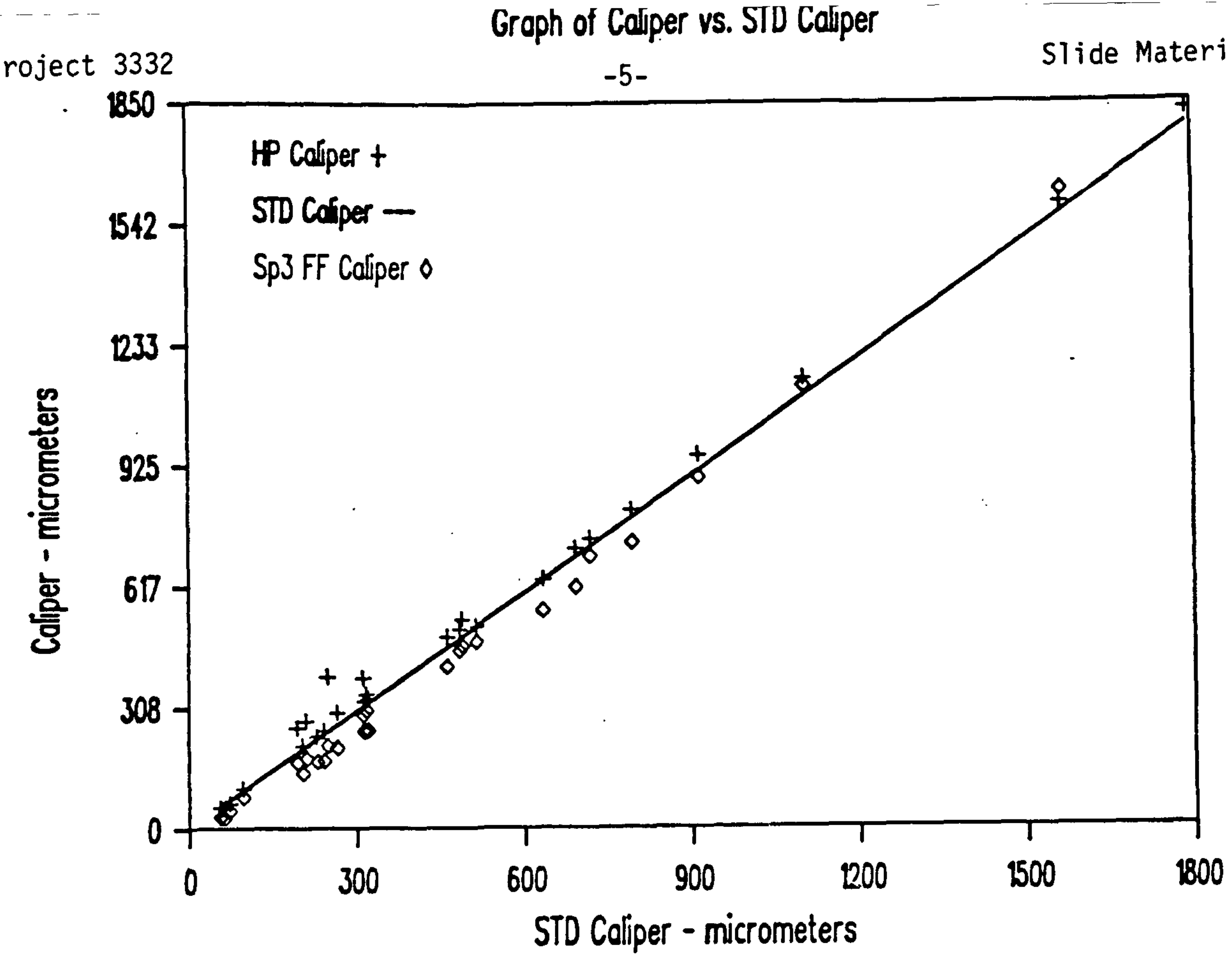
ENDLESS LOOP PATH

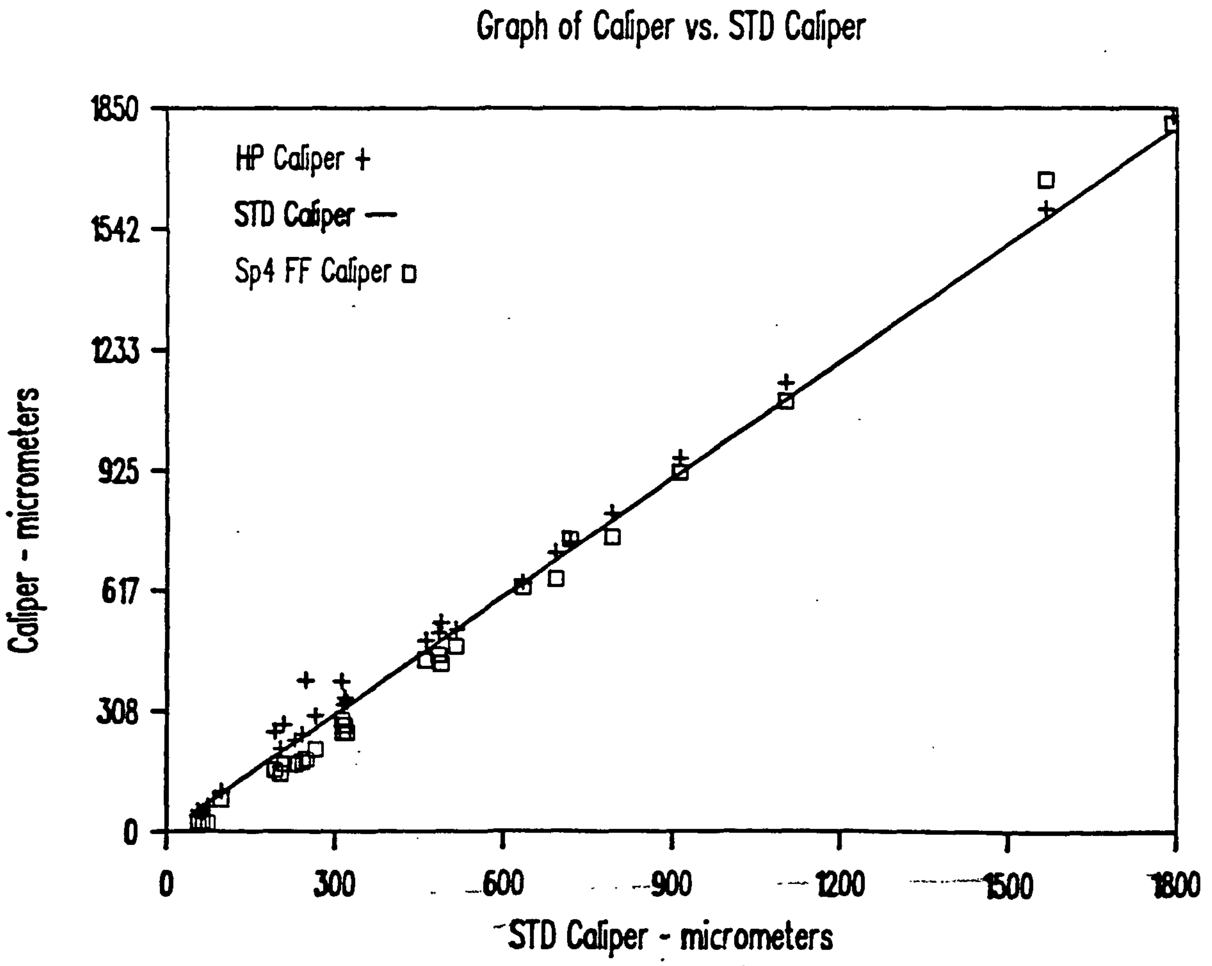



PAPER
RUBBER
RUBBER
T_2
T_1
TRANSMITTER
RECEIVER
T_3
T_1
T_2
T_3


125
100
75
50
25
0
-25
-50
-75
-100
-125
SIGNAL MAGNITUDE (VOLTS)
0
988
TIMEBASE (10 NANOSEC/PT)


GAUSS Feb. 21, 1990 2:31:23 PM
Fluid-rubber reflections
160
0
-160
Relative amplitude
118
122
126
130
134
138
142
146
150
Time (μs)


Graph of Caliper vs. STD Caliper
HP Caliper +
STD Caliper —
Sp3 FF Caliper ◊
Caliper - micrometers
STD Caliper - micrometers
1850
1542
1233
925
617
308
0
0
300
600
900
1200
1500
1800


Graph of Caliper vs. STD Caliper
HP Caliper +
STD Caliper —
Sp4 FF Caliper □
Caliper - micrometers
STD Caliper - micrometers
1850
1542
1233
925
617
308
0
0
300
600
900
1200
1500
1800

PROCESS, PRODUCT, PROPERTIES RELATIONSHIPS

SLIDE MATERIAL

FOR

PROJECT 3467

TO THE

PAPER PROPERTIES AND USES

PROJECT ADVISORY COMMITTEE

March 21, 1990

PROJECT NO. 3467

PROCESS, PROPERTIES, PRODUCT RELATIONSHIPS

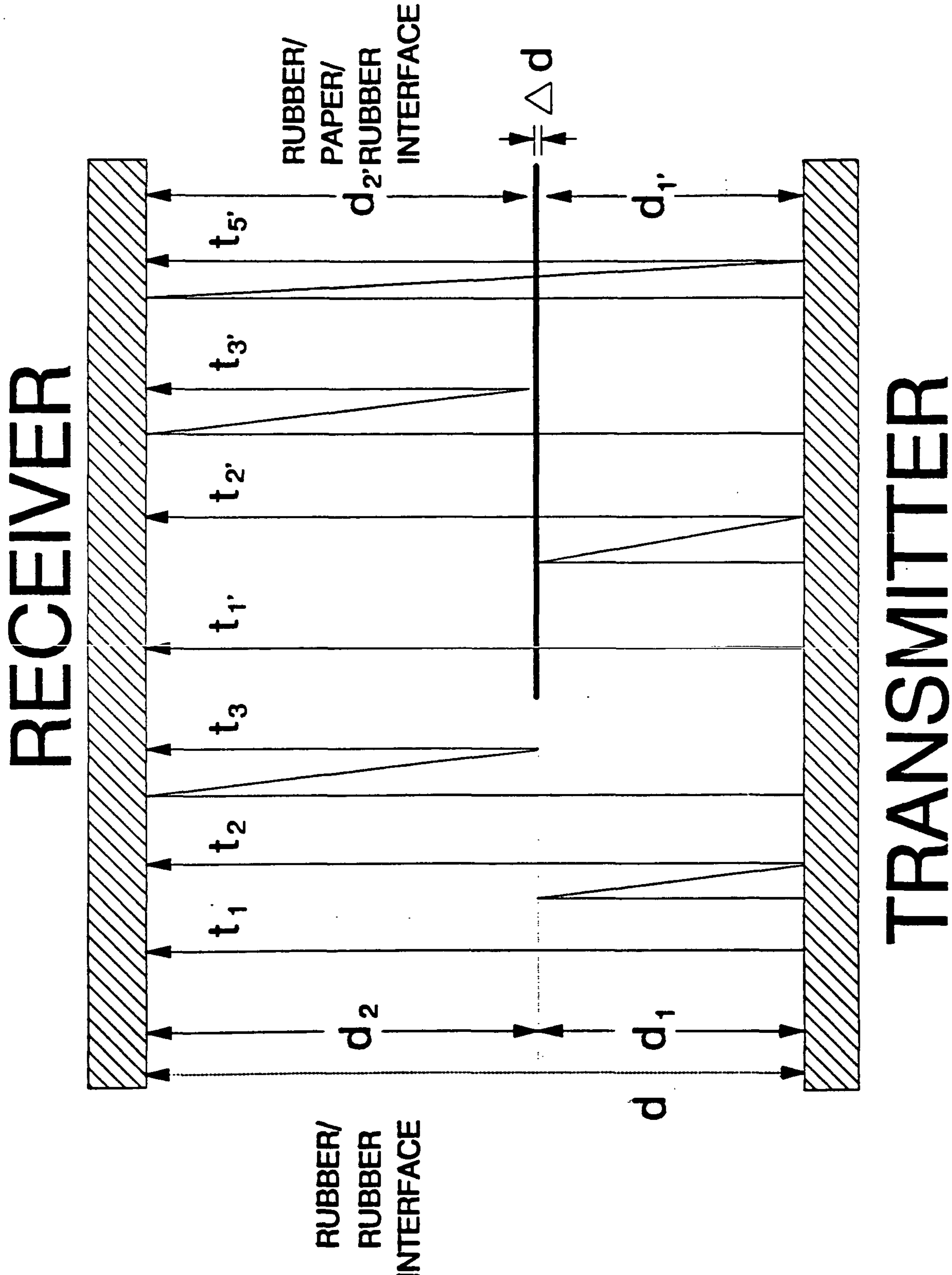
OUTLINE

- PROJECT OBJECTIVES
- OUT-OF-PLANE FLUID-FILLED WHEELS SETUP:
  - Signal processing
  - Frequency domain analysis
- IN-PLANE ULTRASONIC ROBOT TESTER:
  - Polar diagram lean angle accuracy
- FUTURE WORK

PROJECT OBJECTIVES

- Investigate physical properties of paper and board materials.
- Relate measured parameters to end-use performance.
- Relate measured parameters to machine and process variables.

OUT-OF-PLANE FLUID-FILLED WHEELS SETUP


RECEIVER
TRANSMITTER
RUBBER/
PAPER/
RUBBER
INTERFACE
RUBBER/
RUBBER
INTERFACE
Δd
$d_{2'}$
$d_{1'}$
d_2
d_1
d
t_1
t_2
t_3
$t_{1'}$
$t_{2'}$
$t_{3'}$
$t_{5'}$

Reference signals (captured without paper):

$t_1 = d/v_f$

$t_2 = (d + 2\, d_1)/v_f$

$t_3 = (d + 2\, d_2)/v_f$

Paper signals:

$t_{1'} = \Delta t + (d - \Delta d)/v_f$

$t_{2'} = \Delta t + (d - 2d_{1'} - \Delta d)/v_f$

$t_{3'} = \Delta t + (d - 2d_{2'} - \Delta d)/v_f$

$t_{5'} = 3\, t_{1'}$

Apparent sound velocity in fluid:

$$v_f = (2d)/(\Delta t_{21} + \Delta t_{31})$$

Caliper:

$$\Delta d = v_f(\Delta t_{1'1} - (\Delta t_{2'2} + \Delta t_{3'3})/2)$$

$$\Delta d = d - v_f(\Delta t_{2'1'} + \Delta t_{3'1'})/2$$

Transit time:

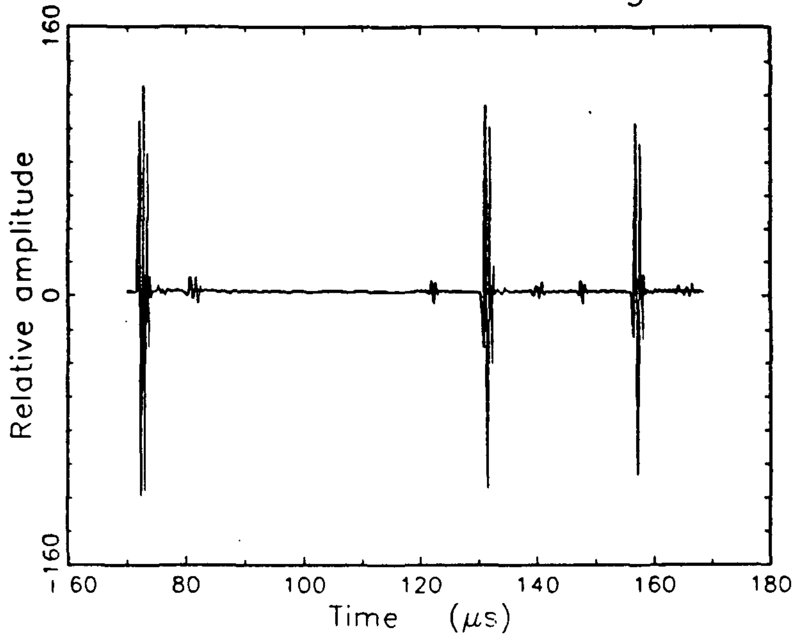
$$\Delta t = \Delta t_{1'1} + \Delta d/v_f$$

$$\Delta t = \Delta t_{5'1'} + (\Delta d - d)/v_f$$

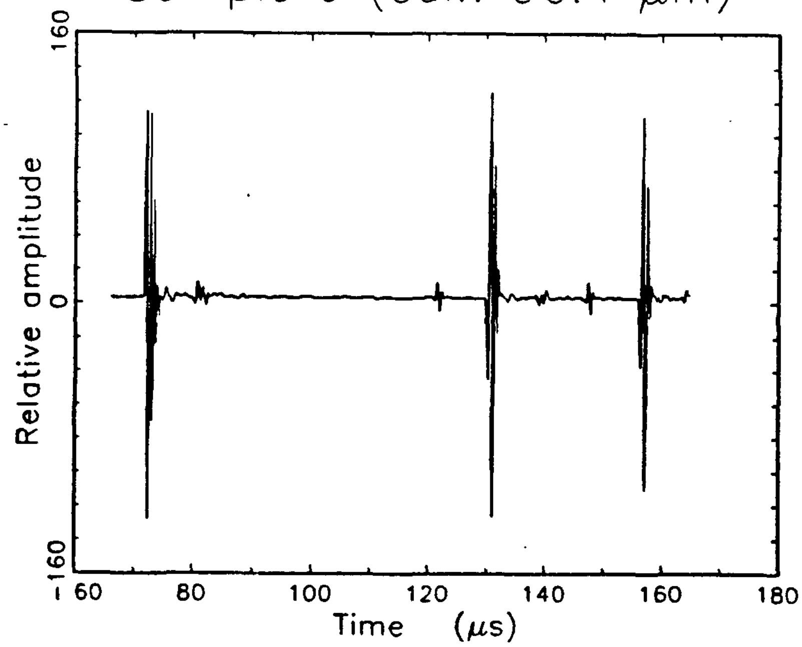
Sound velocity in paper:

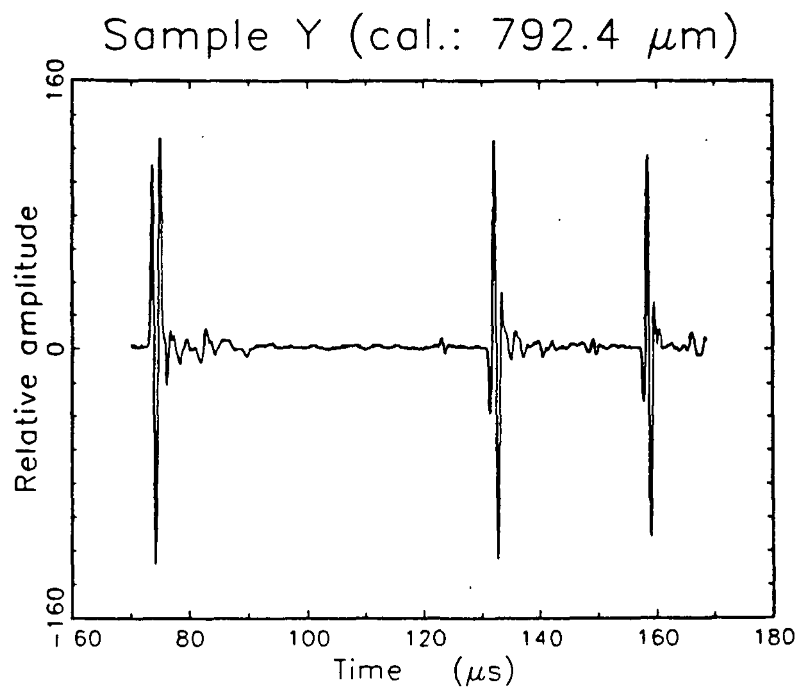
$$v_p = \Delta d/\Delta t$$

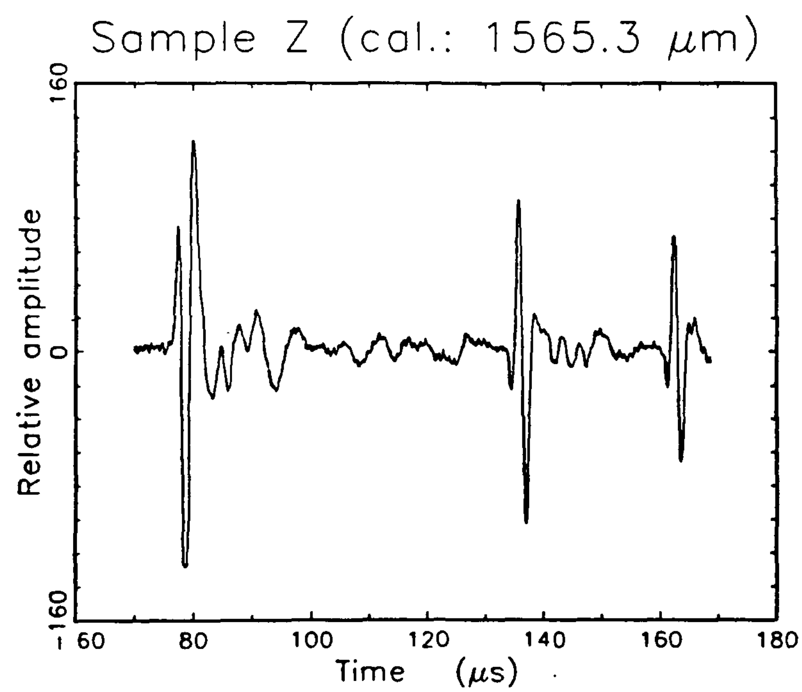
Reference transient signals

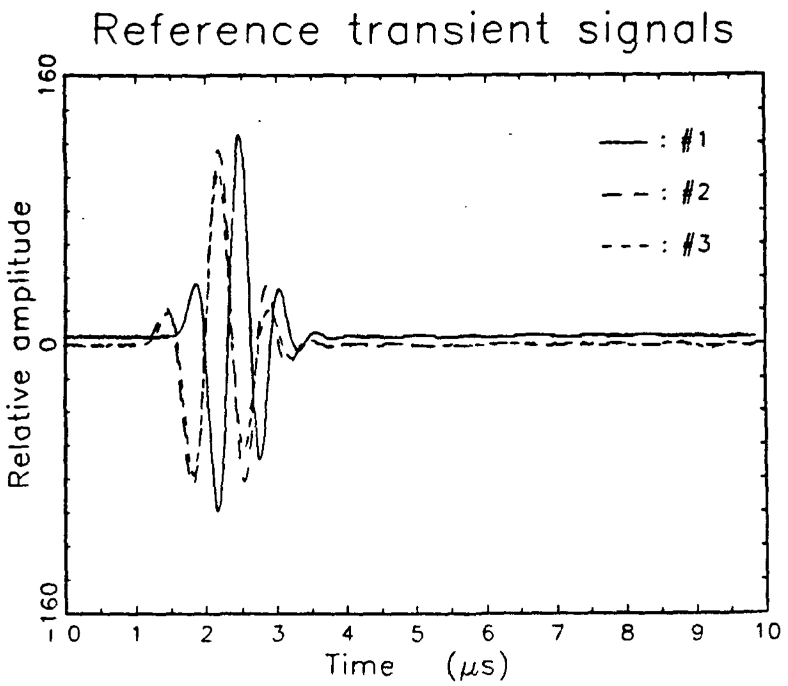


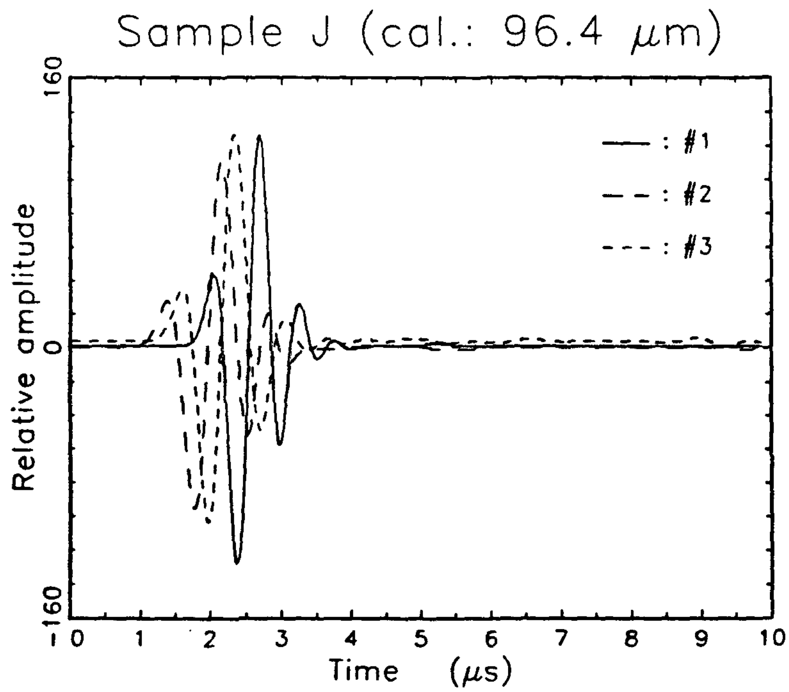
Sample J (cal.: 96.4 μm)

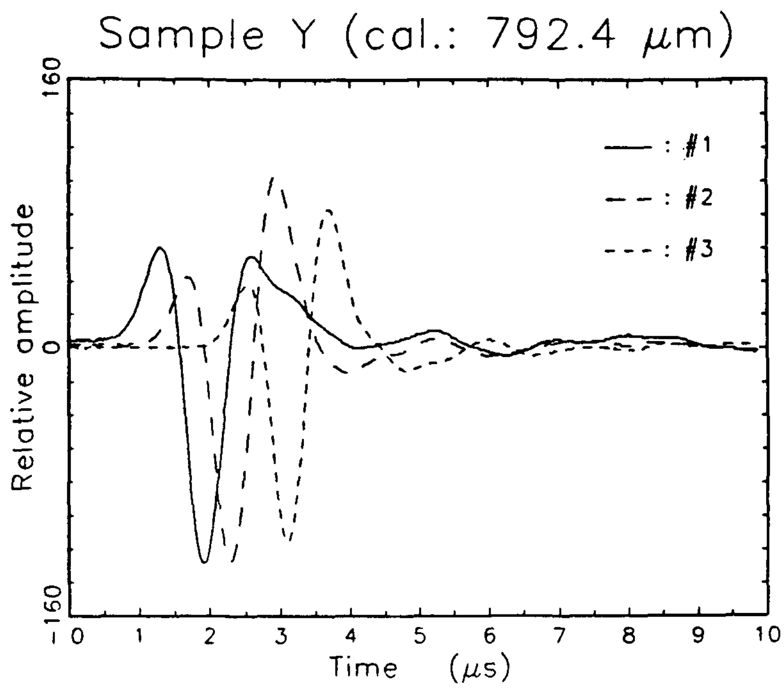


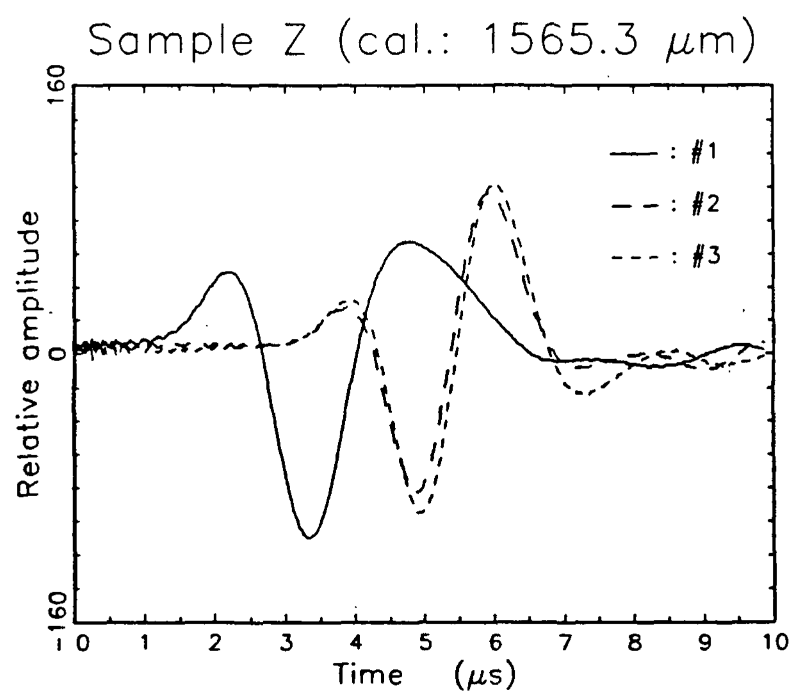

Sample Y (cal.: 792.4 μm)
160
Relative amplitude
0
160
60
80
100
120
140
160
180
Time (μs)

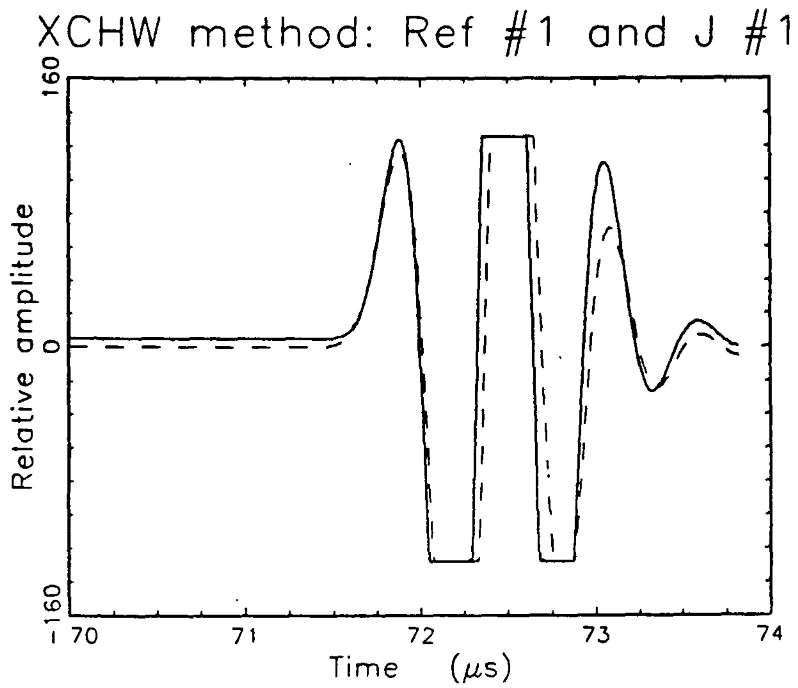

Sample Z (cal.: 1565.3 μm)
160
Relative amplitude
0
160
60
80
100
120
140
160
180
Time (μs)

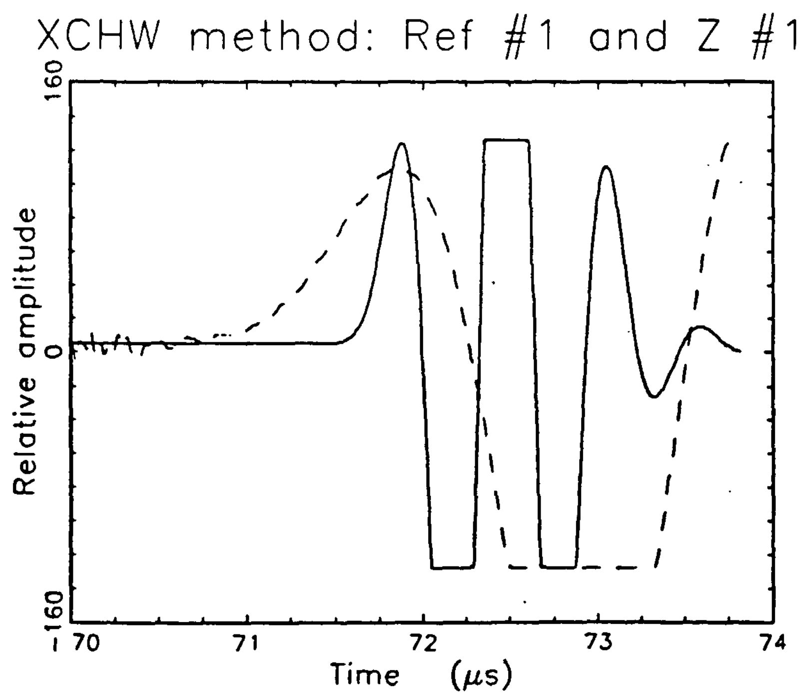

Reference transient signals
160
0
-160
Relative amplitude
—— : #1
— — : #2
- - - : #3
0 1 2 3 4 5 6 7 8 9 10
Time (μs)

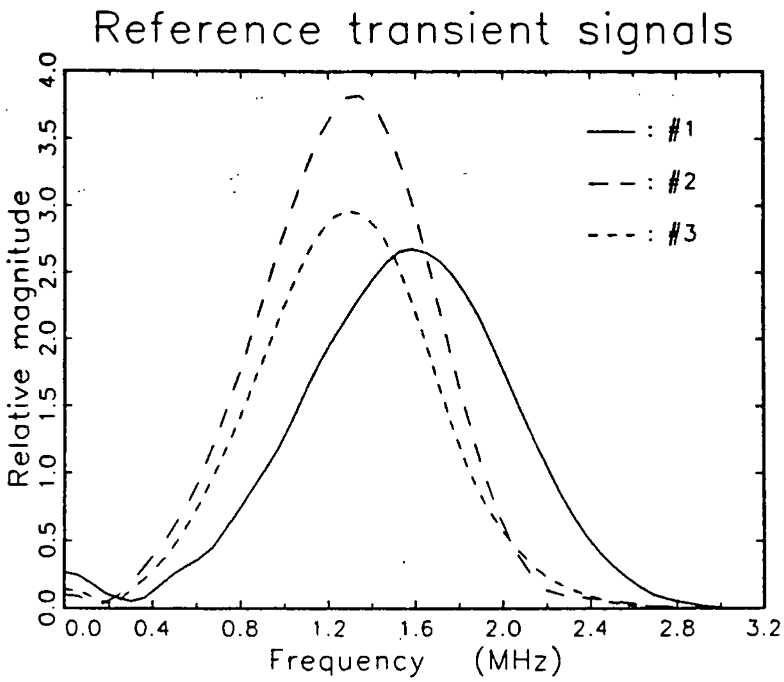

Sample J (cal.: 96.4 μm)
160
0
-160
Relative amplitude
—— : #1
— — : #2
- - - : #3
0 1 2 3 4 5 6 7 8 9 10
Time (μs)

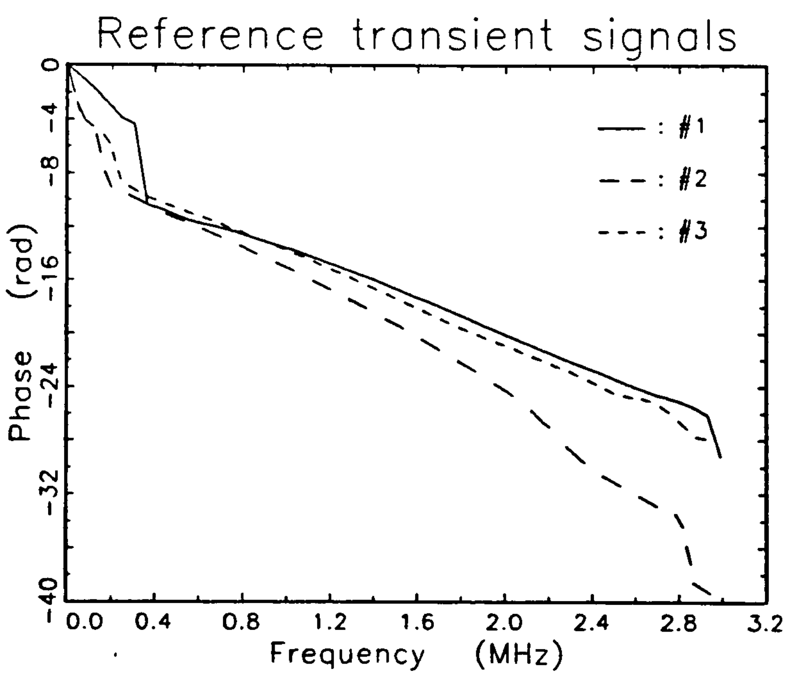

Sample Y (cal.: 792.4 μm)
160
Relative amplitude
0
-160
—— : #1
— — : #2
- - - : #3
0
1
2
3
4
5
6
7
8
9
10
Time (μs)

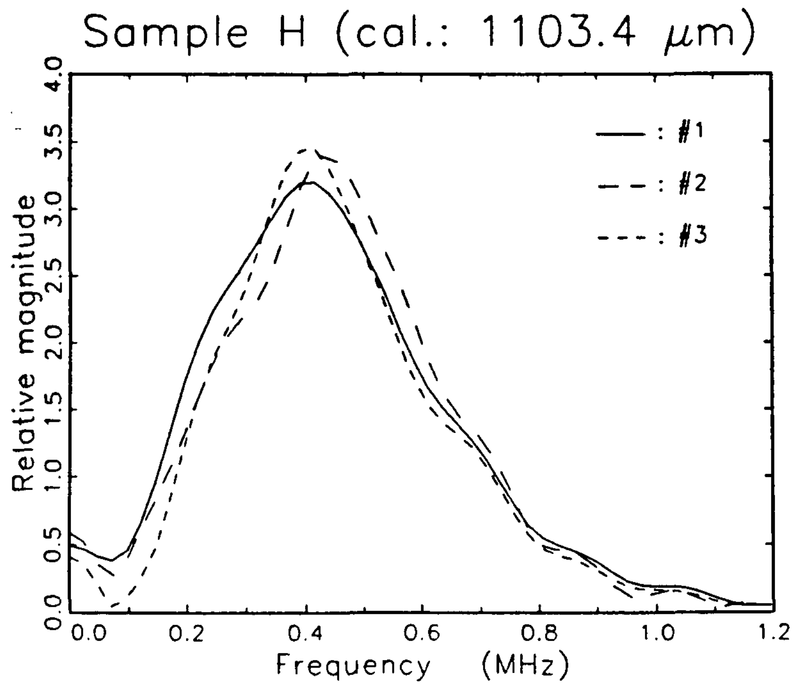

Sample Z (cal.: 1565.3 μm)
160
Relative amplitude
0
-160
—— : #1
— — : #2
- - - : #3
0
1
2
3
4
5
6
7
8
9
10
Time (μs)

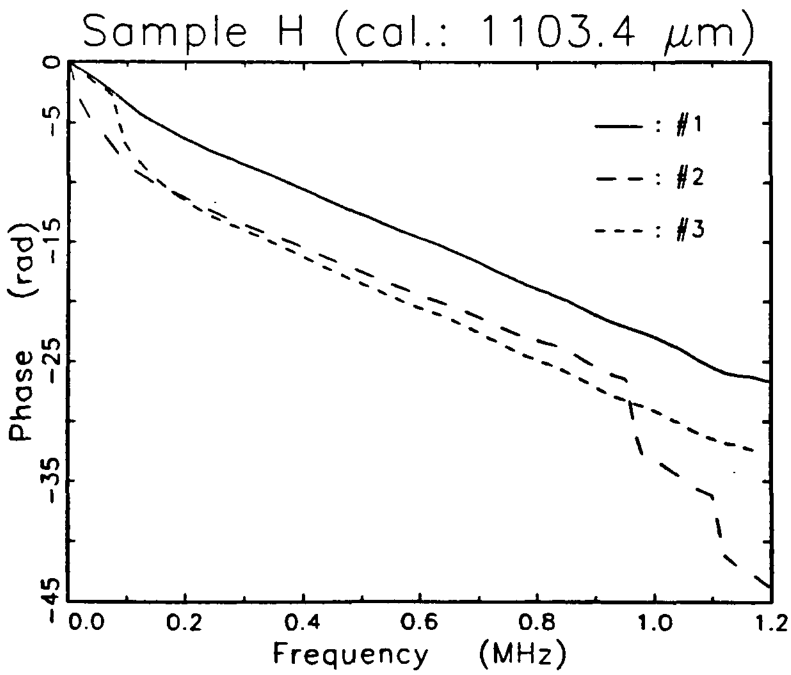

XCHW method: Ref #1 and J #1
160
0
-160
Relative amplitude
70
71
72
73
74
Time (μs)

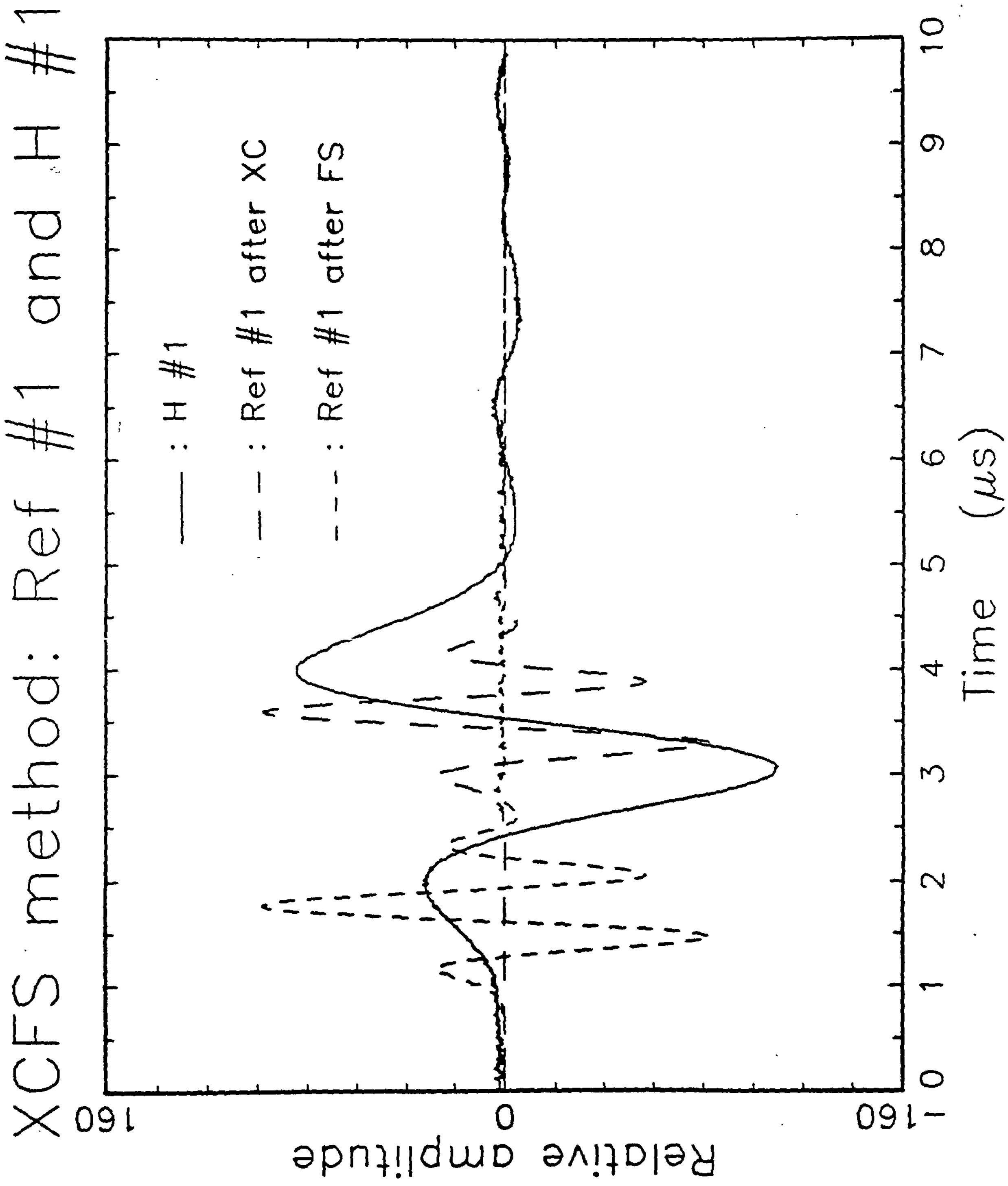

XCHW method: Ref #1 and Z #1
160
0
-160
Relative amplitude
70
71
72
73
74
Time (μs)

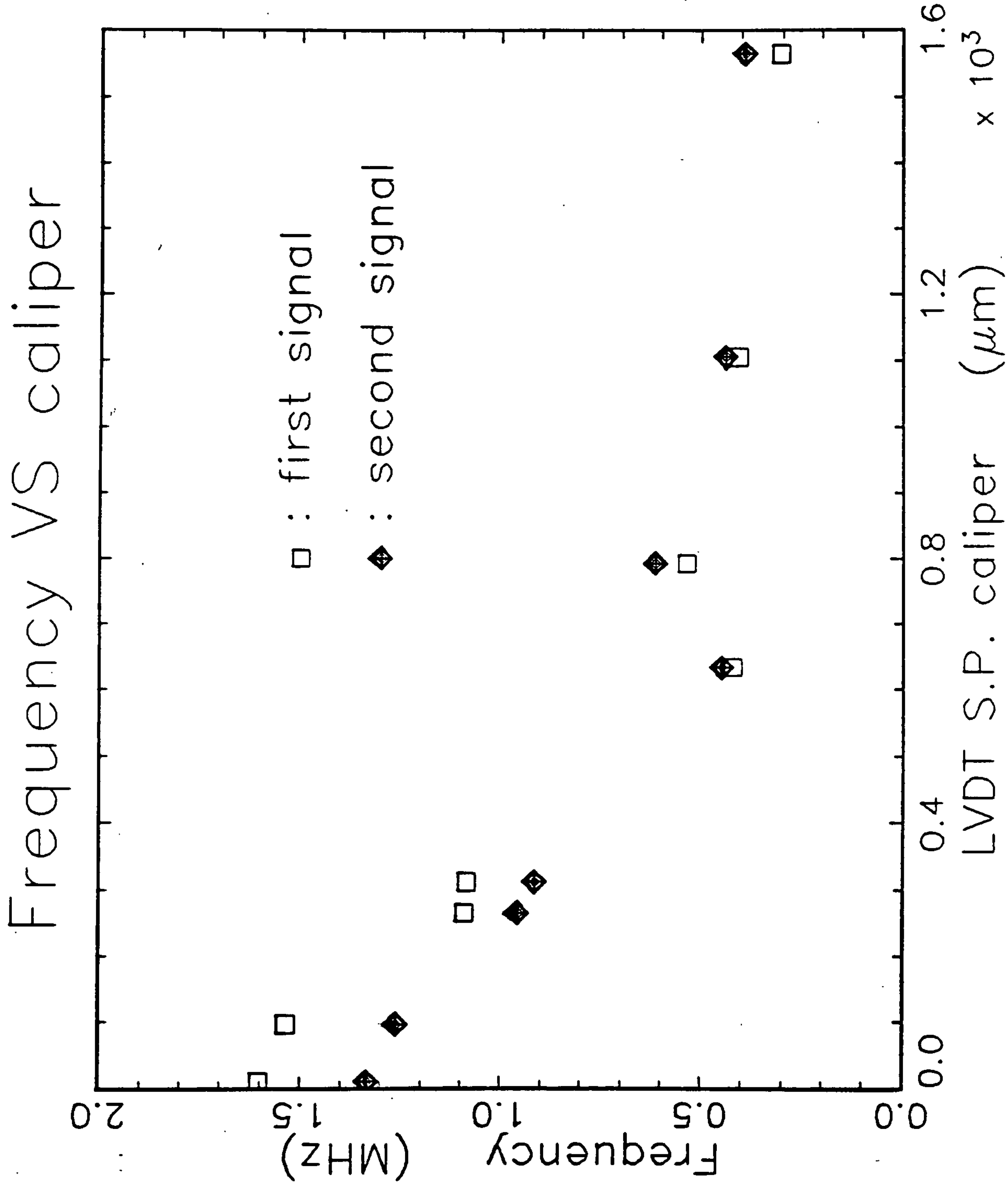

Reference transient signals
Relative magnitude
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2
Frequency (MHz)
: #1
: #2
: #3


Reference transient signals
Phase (rad)
0
-4
-8
-16
-24
-32
-40
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2
Frequency (MHz)
: #1
: #2
: #3


Sample H (cal.: 1103.4 μm)
Relative magnitude
Frequency (MHz)
: #1
: #2
: #3
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0.2
0.4
0.6
0.8
1.0
1.2


Sample H (cal.: 1103.4 μm)
Phase (rad)
Frequency (MHz)
: #1
: #2
: #3
0
-5
-15
-25
-35
-45
0.0
0.2
0.4
0.6
0.8
1.0
1.2


XCFS method: Ref #1 and H #1
—— : H #1
- - : Ref #1 after XC
-- - : Ref #1 after FS
Relative amplitude
160
0
-160
Time (μs)
0
1
2
3
4
5
6
7
8
9
10


Frequency VS caliper
□ : first signal
◆ : second signal
Frequency (MHz)
0.0
0.5
1.0
1.5
2.0
LVDT S.P. caliper (μm)
0.0
0.4
0.8
1.2
1.6
x 10^3

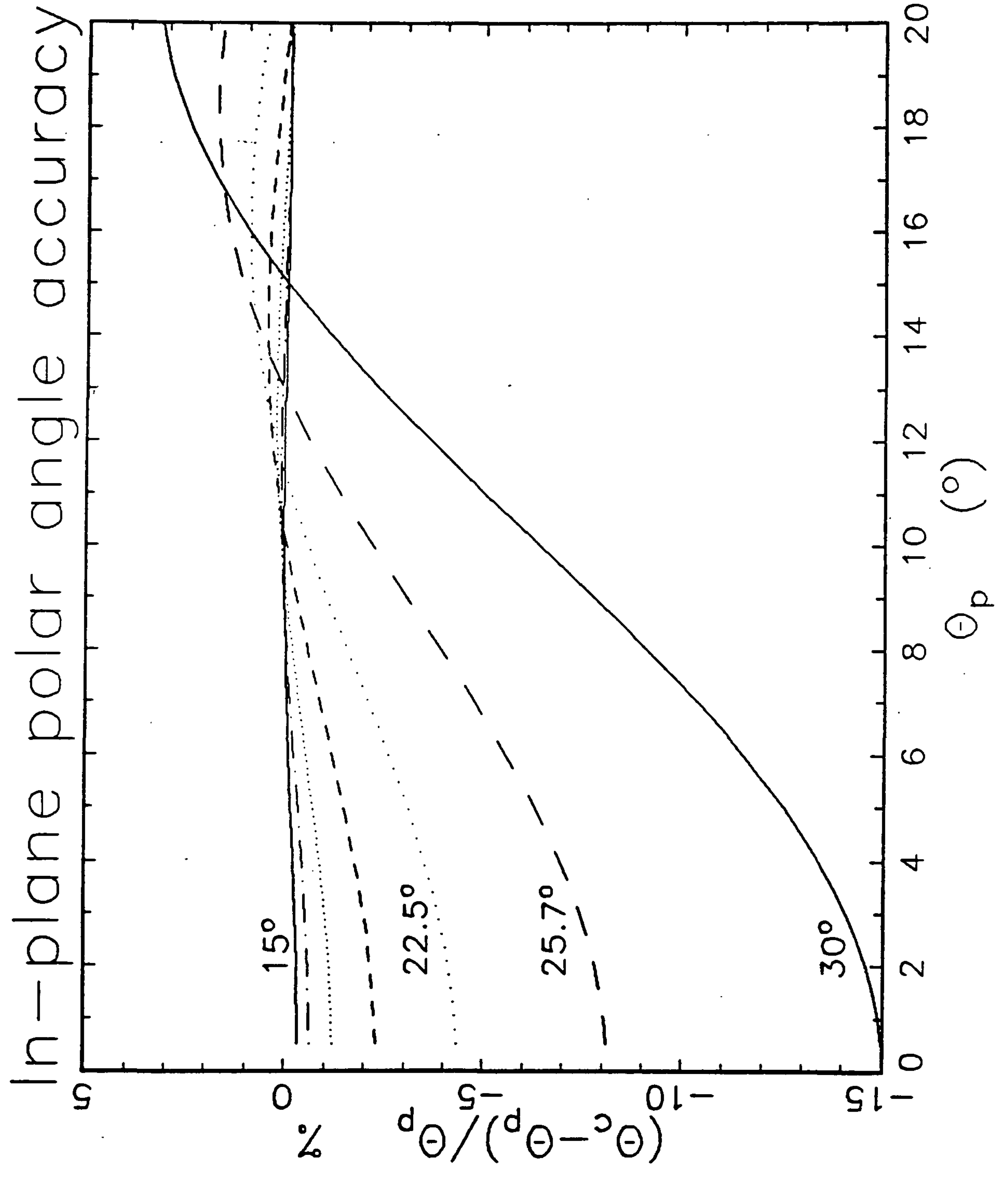
IN-PLANE ULTRASONIC ROBOT TESTER:

---> Polar diagram lean angle accuracy

- Typical polar diagram simulated by an ellipse

- For a predicted lean angle, polar diagram data points computed as a function of selected stepping angle

- Lean angle calculated using maximum moment of inertia


In-plane polar angle accuracy
% $(\Theta_c-\Theta_p)/\Theta_p$
Θ_p (°)
15°
22.5°
25.7°
30°
5
0
-5
-10
-15
0
2
4
6
8
10
12
14
16
18
20

FUTURE WORK

- Out-of-plane fluid-filled wheels setup:
    - Continue signal processing development
    - Continue frequency domain analysis
    - Investigate dispersion and sound attenuation

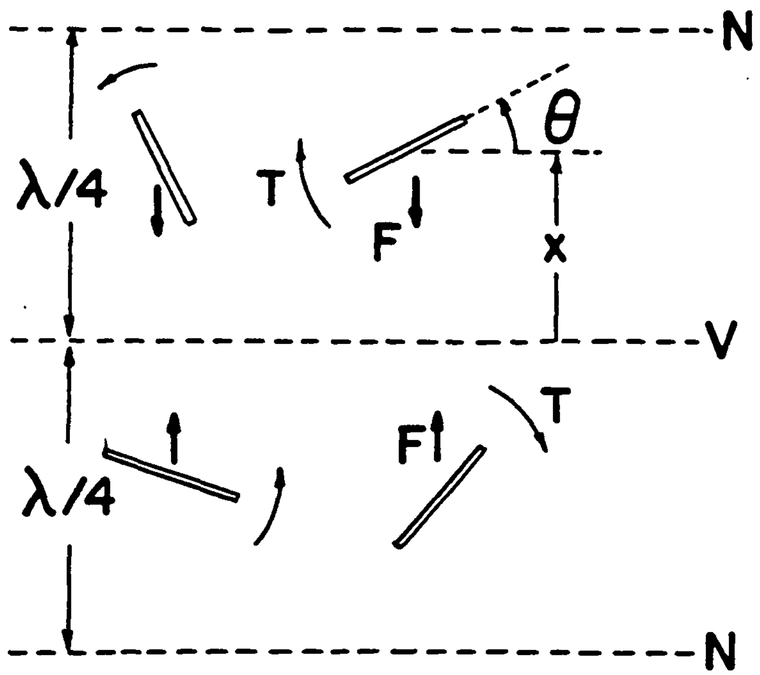
FUTURE WORK

- Fiber orientation anisotropy in paper:
    - Improve microwave attenuation instrument to perform polar diagram measurements
    - Compare in-plane microwave and ultrasonic polar diagram measurements

FUTURE WORK

- Investigate elastic properties of paper submitted to microwave plasma etching

- Explore acoustic radiation pressure effects on fluid suspended fibers


N
θ
λ/4
T
F
x
V
T
F
λ/4
N

STRENGTH IMPROVEMENT AND FAILURE MECHANISMS

SLIDE MATERIAL

FOR

PROJECT 3469

TO THE

PAPER PROPERTIES AND USES

PROJECT ADVISORY COMMITTEE

March 21, 1990

STRENGTH IMPROVEMENT AND FAILURE MECHANISMS

COMPRESSIVE STRENGTH IMPROVEMENT

RAW MATERIALS:

* Evaluation of Fiber Potential
* High Yield Hardwood Pulps
* Inter & Intra Fiber Reinforcement

PAPERMAKING PROCESS:

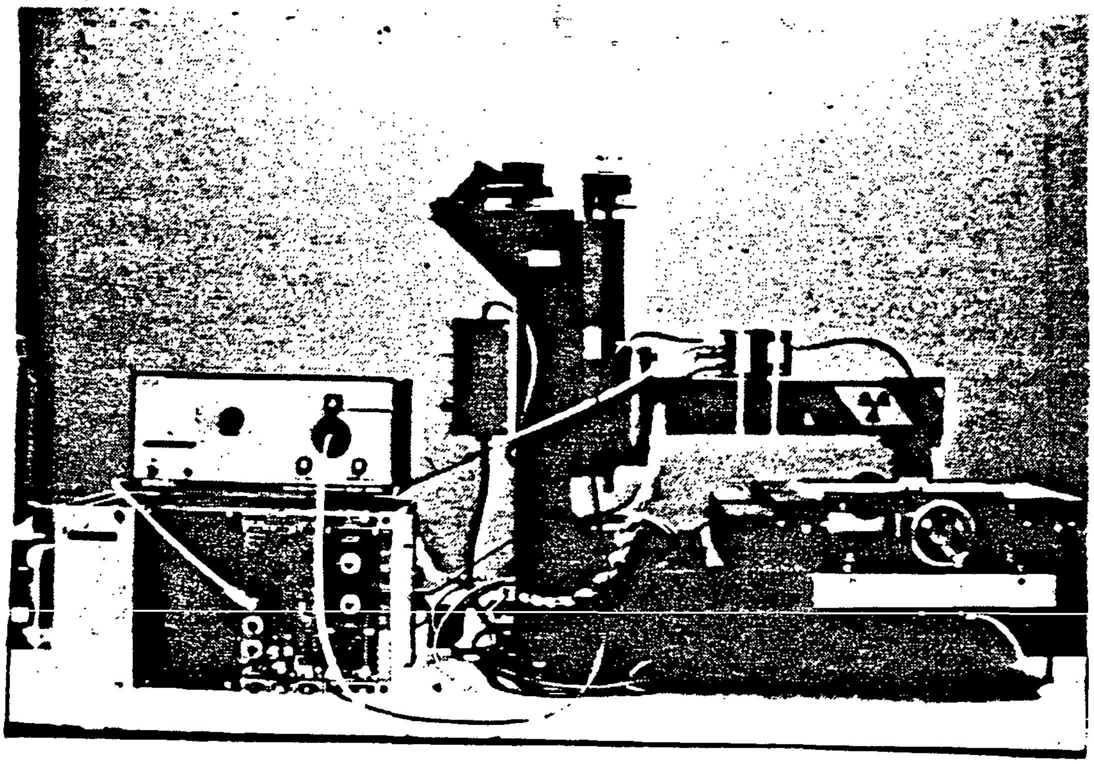
* Refining
* Fiber Orientation
* Forming Consistency
* Wet Pressing & Drying

CORRUGATING:

* Forming Losses

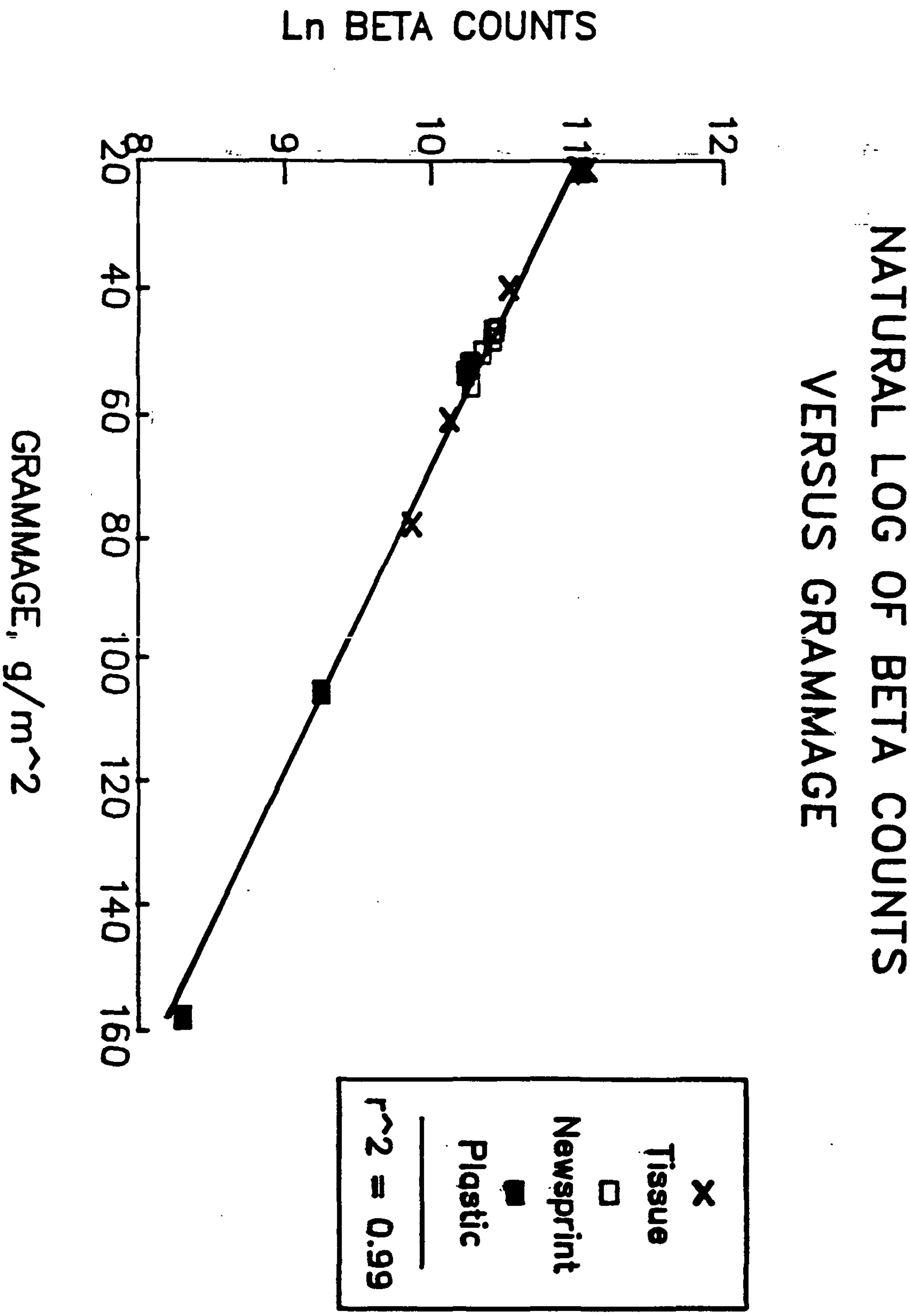
FORMATION MEASUREMENTS

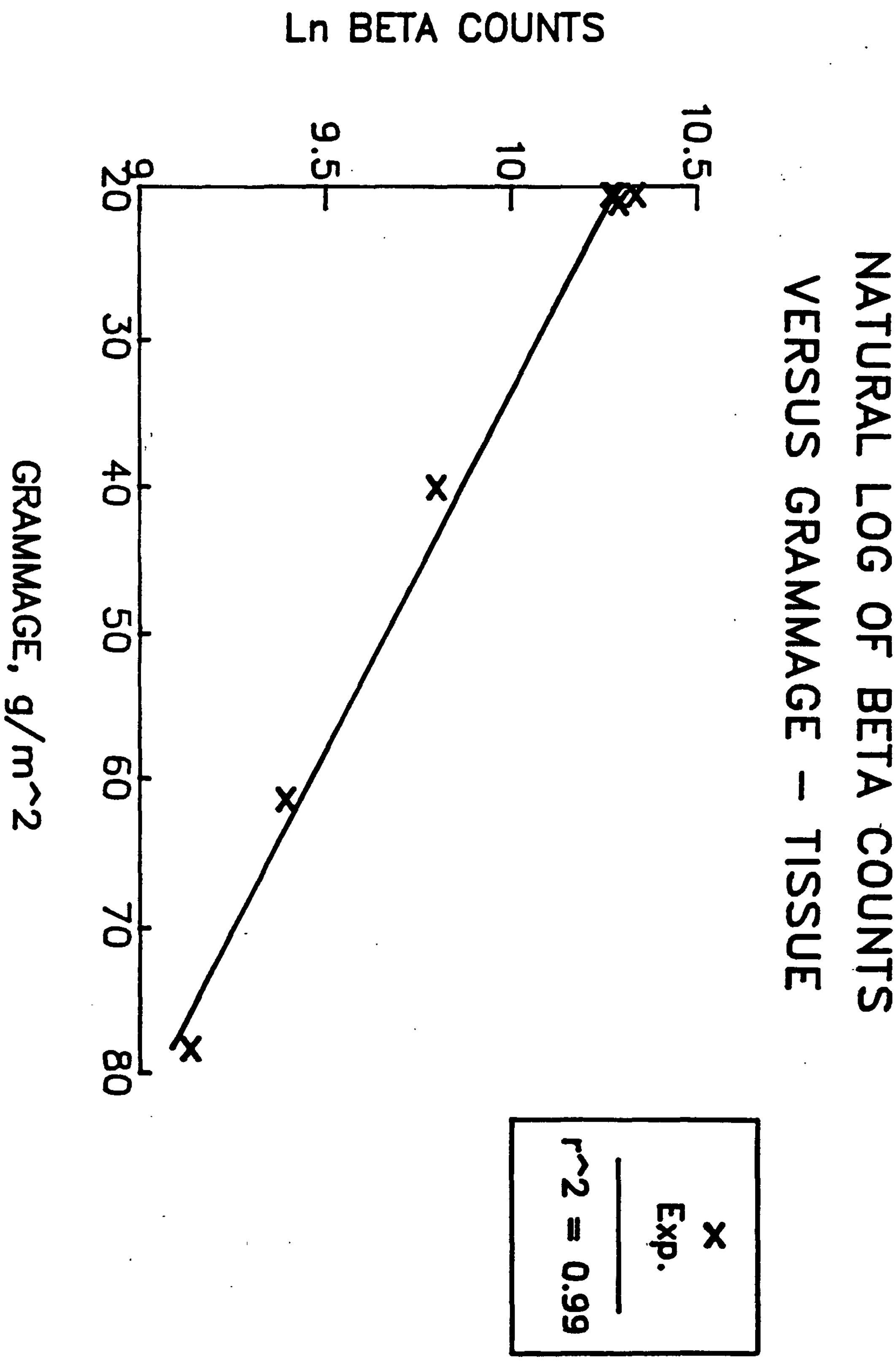
* Visual Uniformity
* Converting and End Use Performance

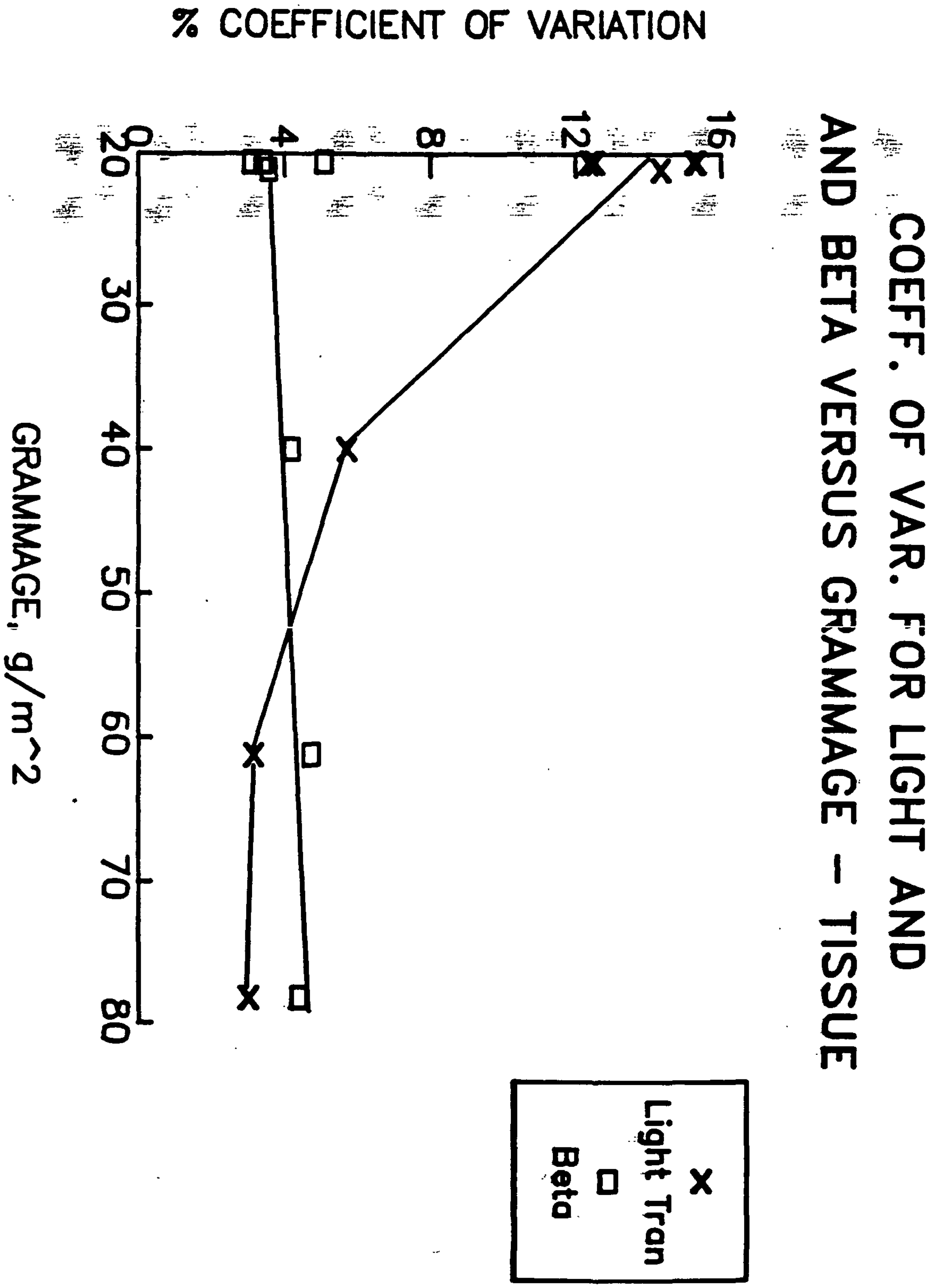


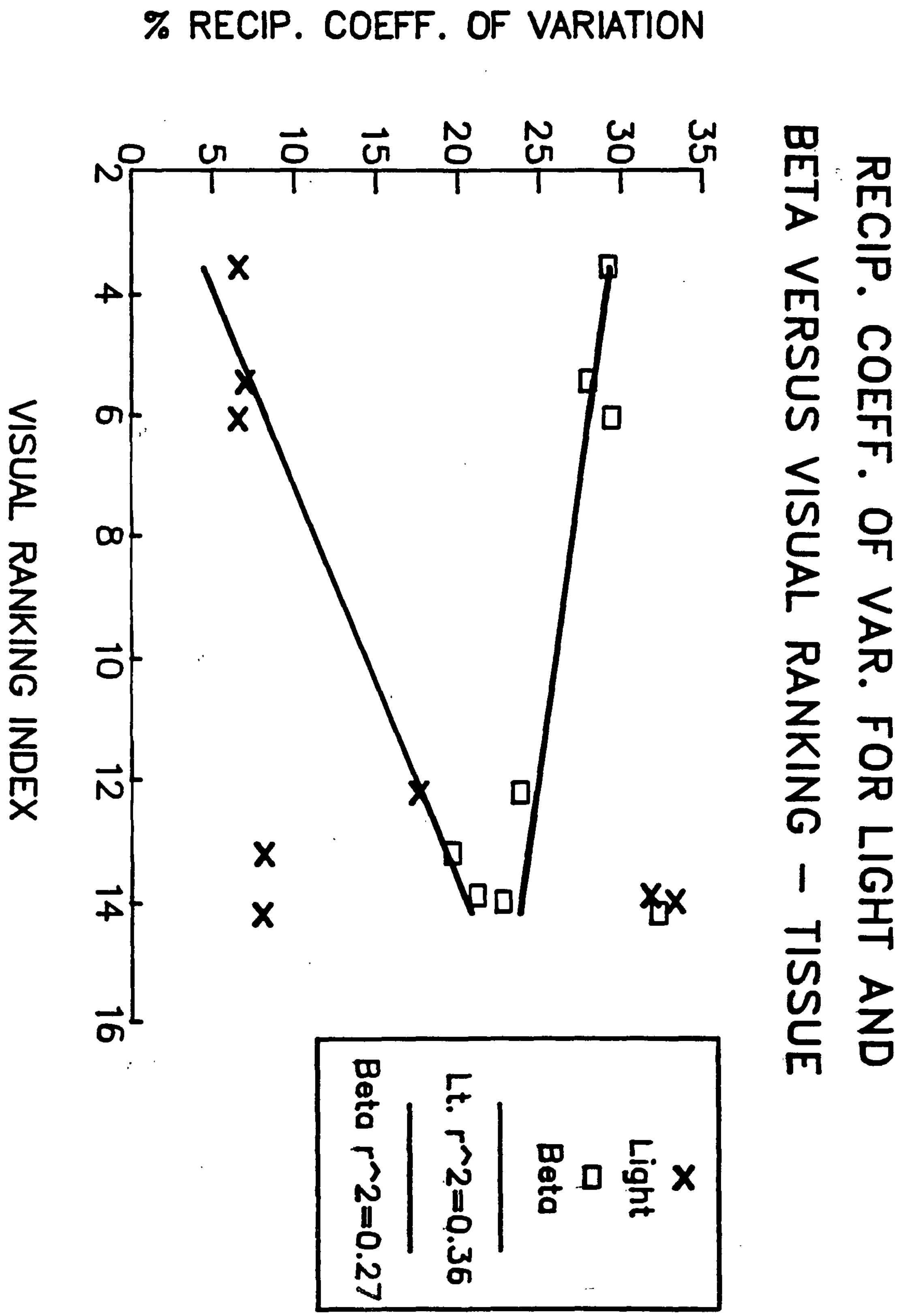
INHERENT VARIABILITY IN BETA PARTICLE COUNTING

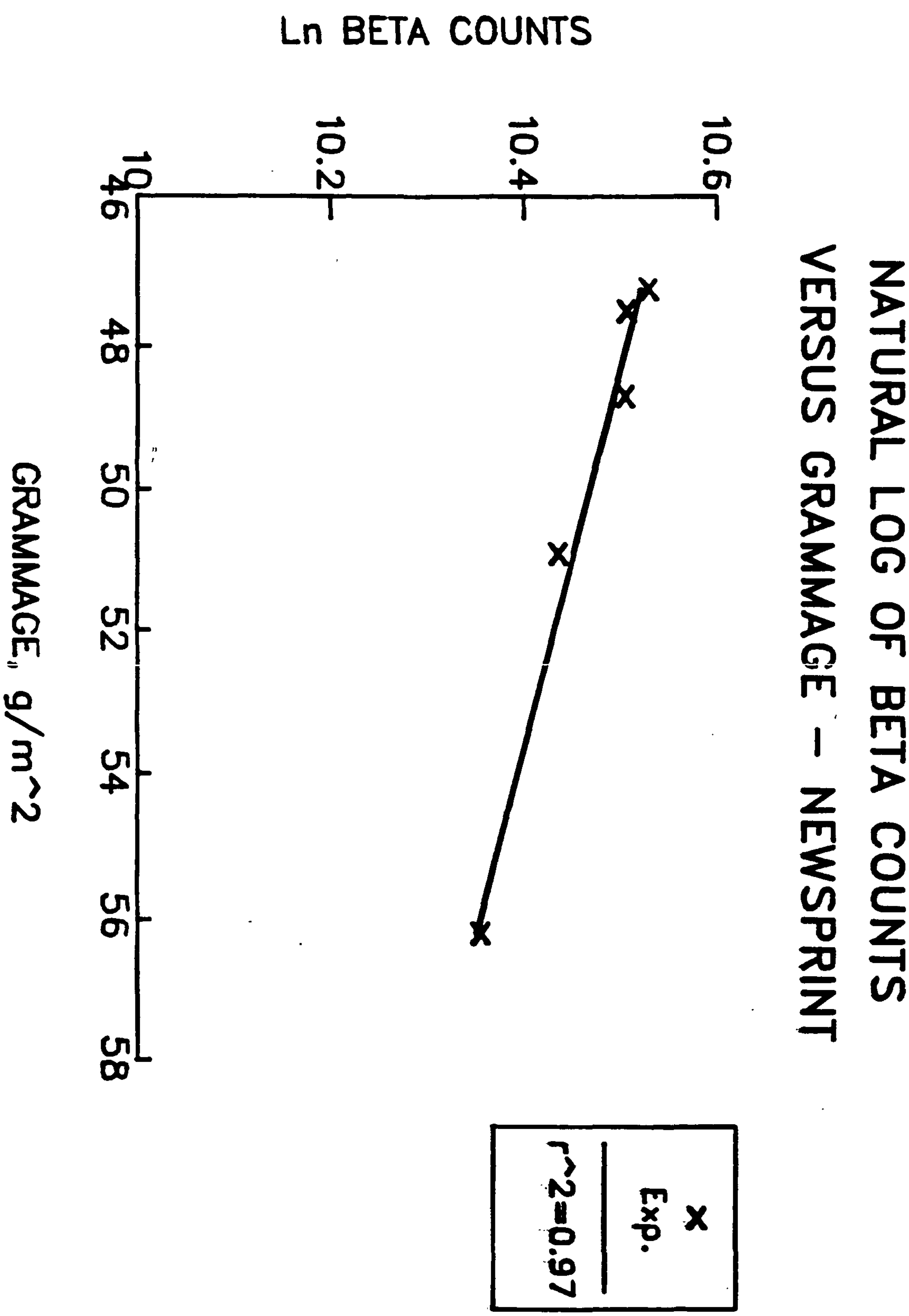
Counting Time secs.	Beta Counts Average	Coeff. of Variation %
2	44988	0.48
5	108877	0.24

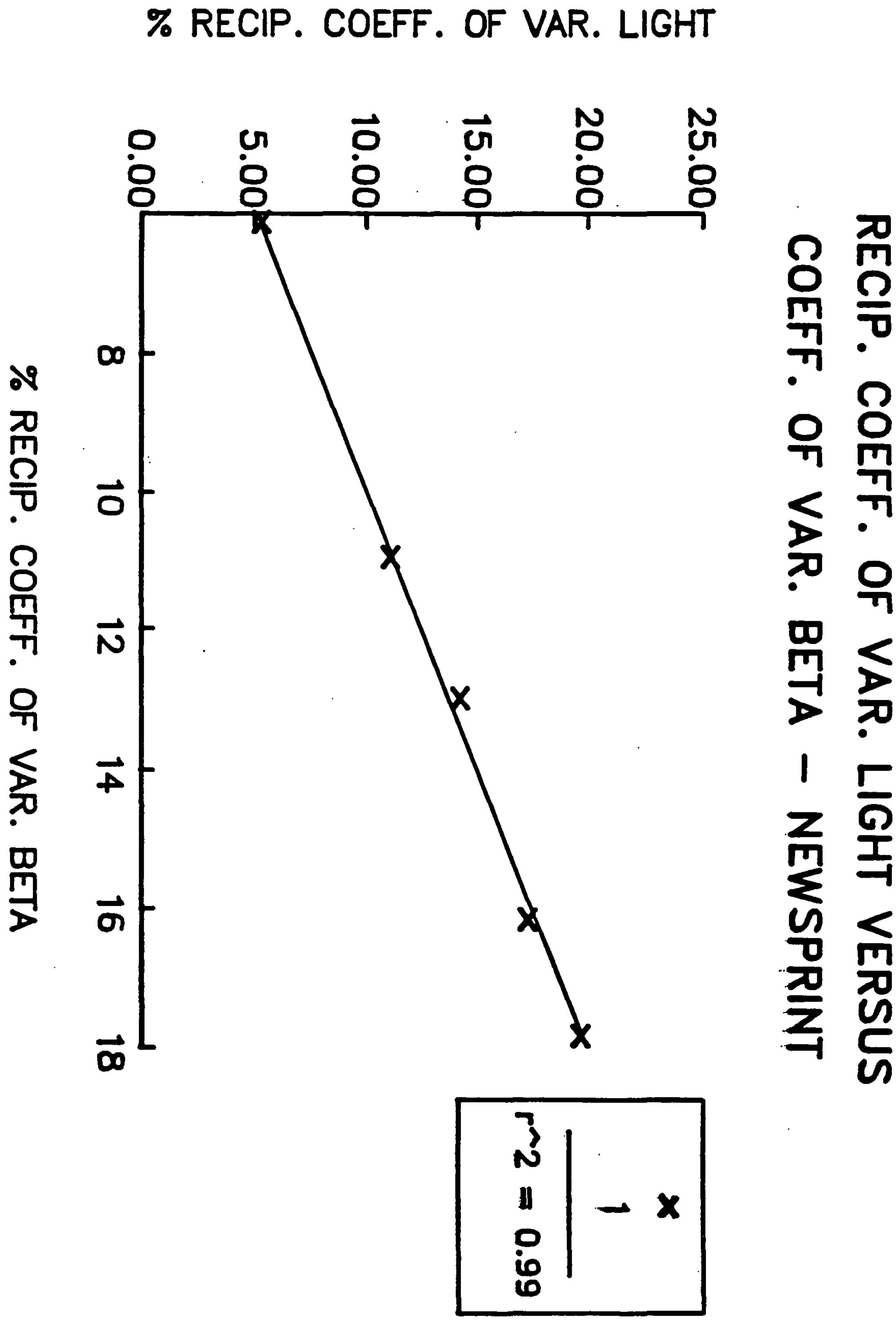

NATURAL LOG OF BETA COUNTS
VERSUS GRAMMAGE
Ln BETA COUNTS
8
9
10
11
12
20
40
60
80
100
120
140
160
GRAMMAGE, g/m^2
Tissue
Newsprint
Plastic
r^2 = 0.99

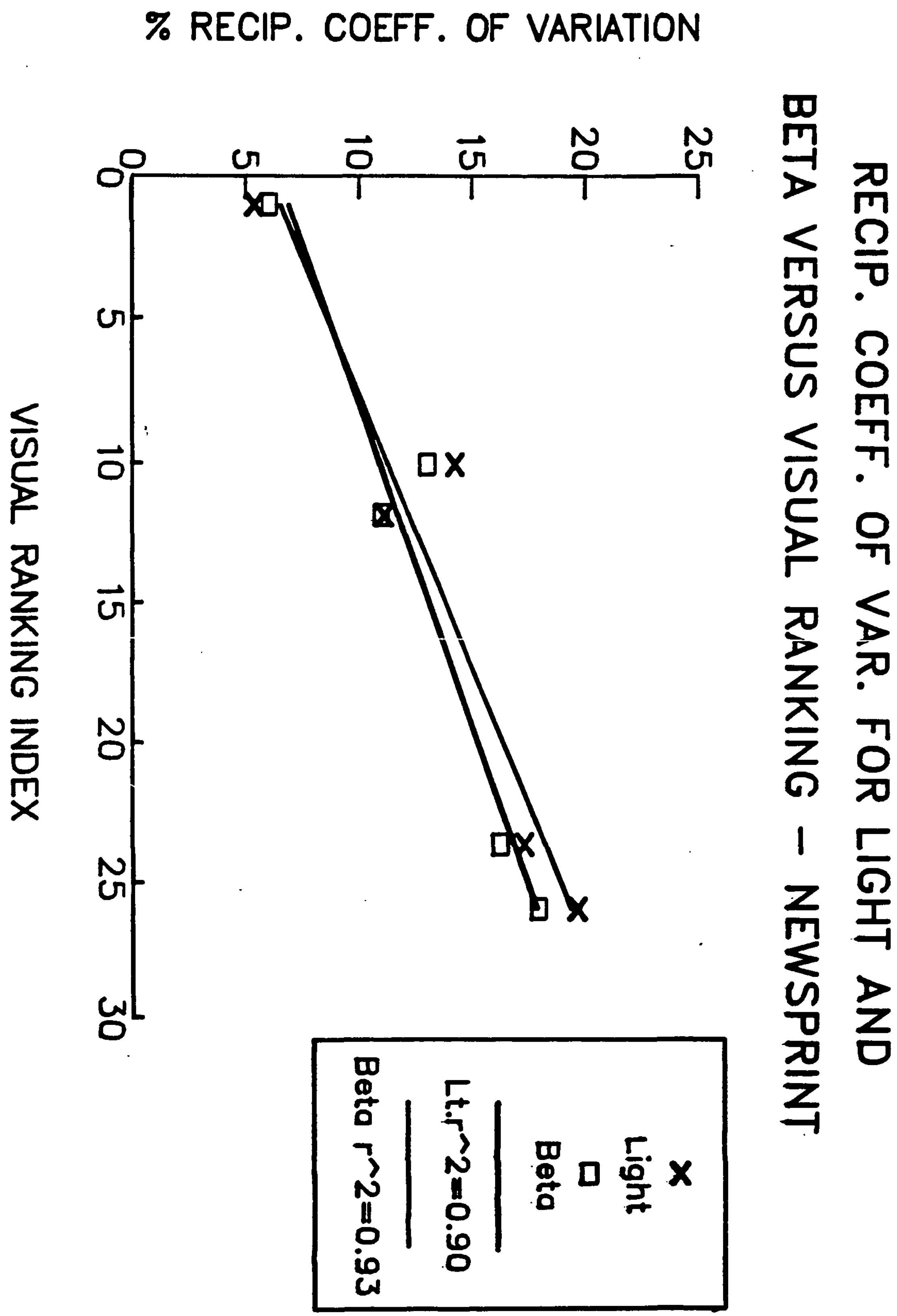

NATURAL LOG OF BETA COUNTS
VERSUS GRAMMAGE – TISSUE
Ln BETA COUNTS
10.5
10
9.5
9
20
30
40
50
60
70
80
GRAMMAGE, g/m^2
x
Exp.
r^2 = 0.99


COEFF. OF VAR. FOR LIGHT AND
AND BETA VERSUS GRAMMAGE – TISSUE
% COEFFICIENT OF VARIATION
0
4
8
12
16
20
30
40
50
60
70
80
GRAMMAGE, g/m^2
Light Tran
Beta


RECIP. COEFF. OF VAR. FOR LIGHT AND
BETA VERSUS VISUAL RANKING – TISSUE
% RECIP. COEFF. OF VARIATION
0
5
10
15
20
25
30
35
2
4
6
8
10
12
14
16
VISUAL RANKING INDEX
Light
Beta
Lt. r^2=0.36
Beta r^2=0.27

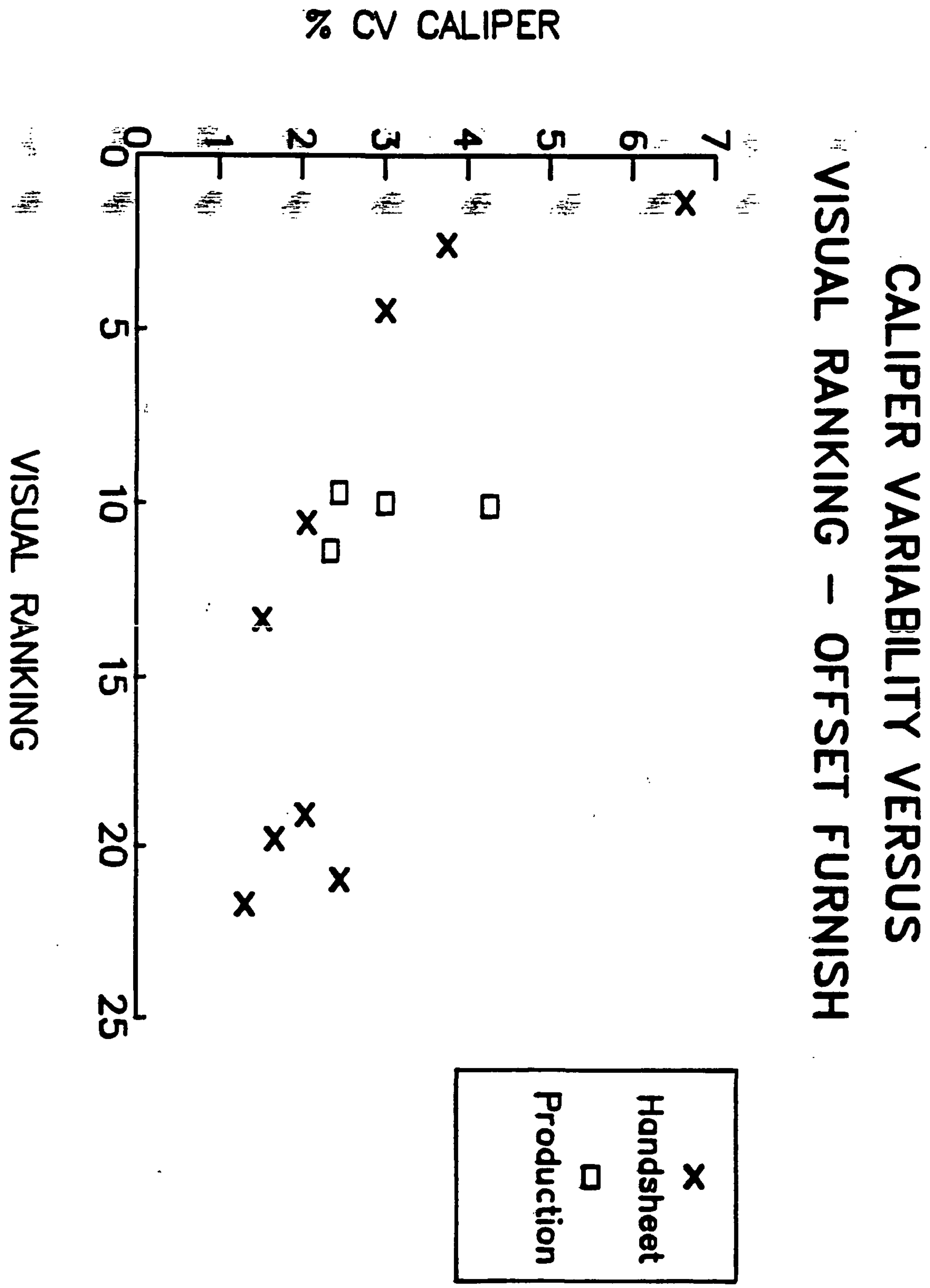

NATURAL LOG OF BETA COUNTS
VERSUS GRAMMAGE - NEWSPRINT
Ln BETA COUNTS
10
10.2
10.4
10.6
46
48
50
52
54
56
58
GRAMMAGE, g/m^2
X
Exp.
r^2=0.97


RECIP. COEFF. OF VAR. LIGHT VERSUS
COEFF. OF VAR. BETA – NEWSPRINT
% RECIP. COEFF. OF VAR. LIGHT
25.00
20.00
15.00
10.00
5.00
0.00
8
10
12
14
16
18
% RECIP. COEFF. OF VAR. BETA
x
1
r^2 = 0.99

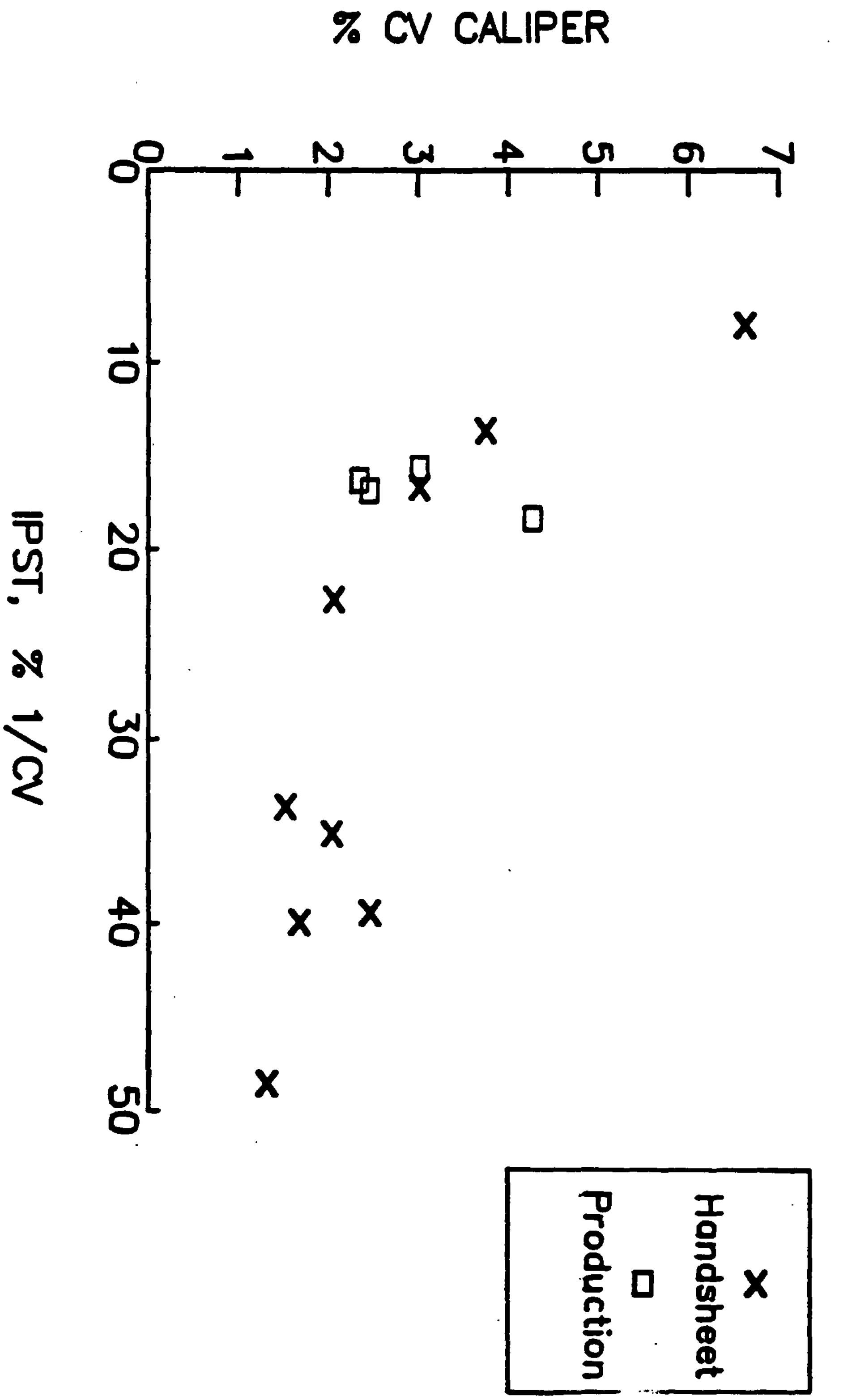

RECIP. COEFF. OF VAR. FOR LIGHT AND
BETA VERSUS VISUAL RANKING – NEWSPRINT
% RECIP. COEFF. OF VARIATION
0
5
10
15
20
25
0
5
10
15
20
25
30
VISUAL RANKING INDEX
Light
Beta
Lt.r^2=0.90
Beta r^2=0.93

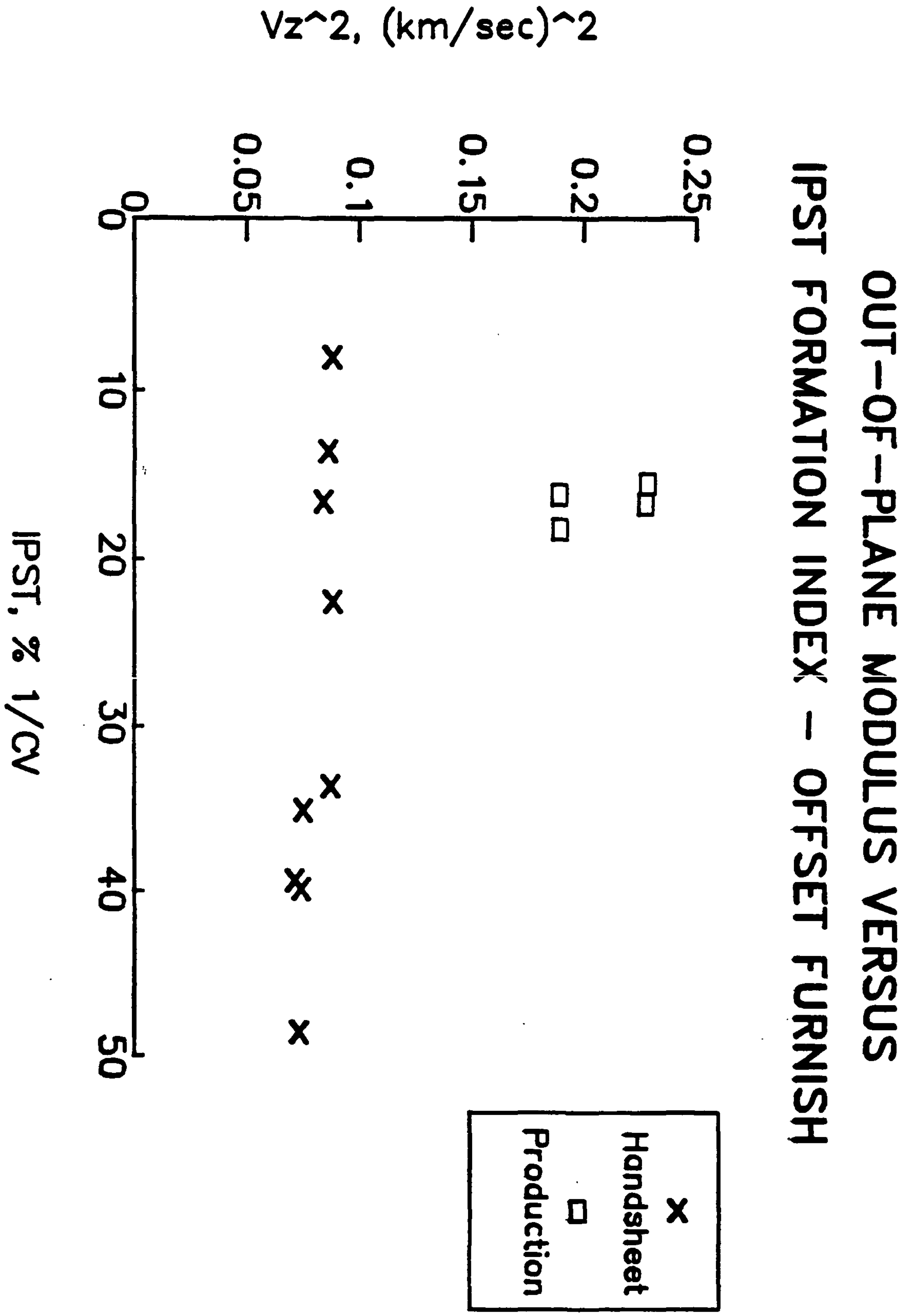
DEPENDENCE OF PAPER PROPERTIES ON FORMATION

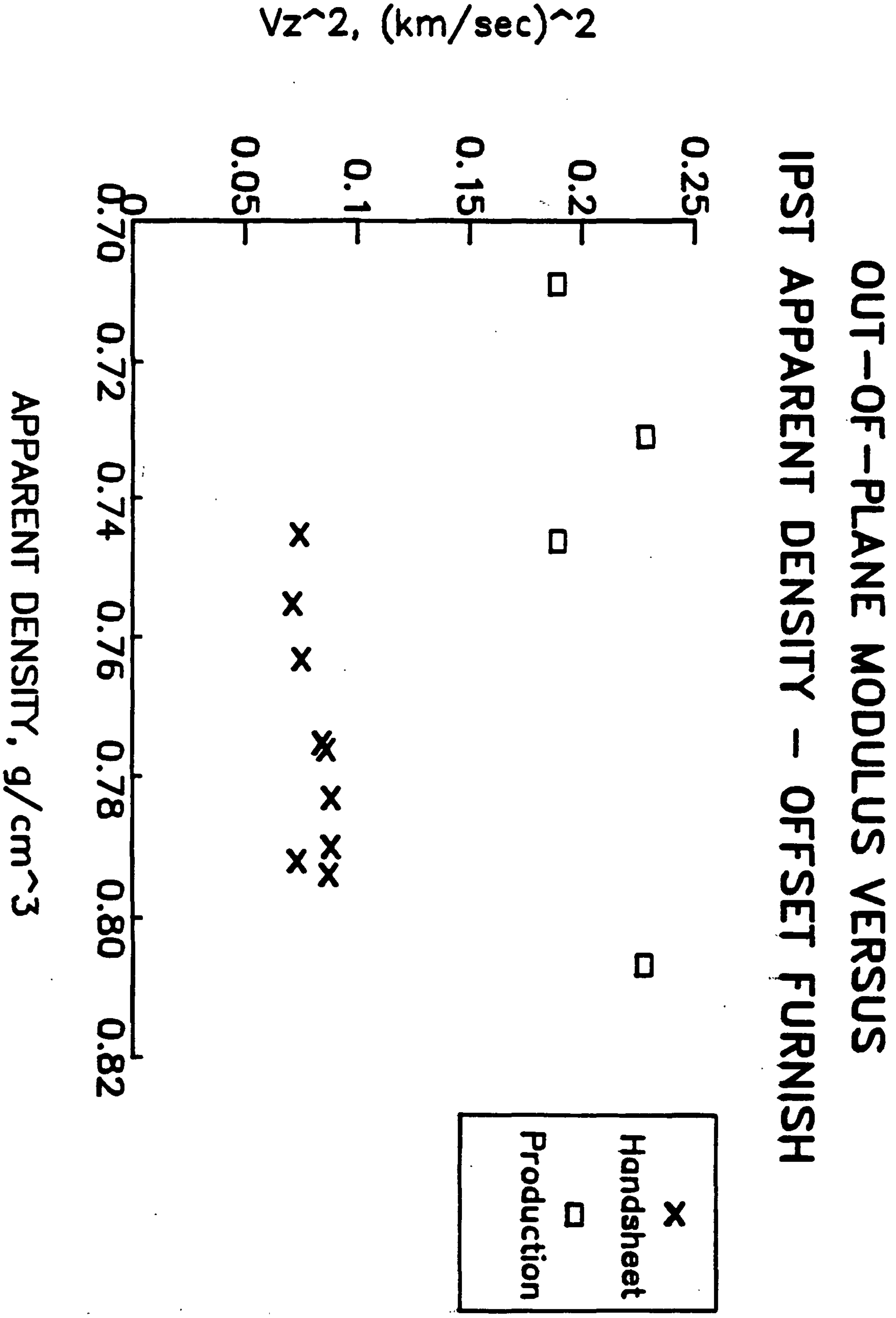
* Caliper
* Elastic Properties
* Tensile & Fracture Properties
* Porosity
* Smoothness

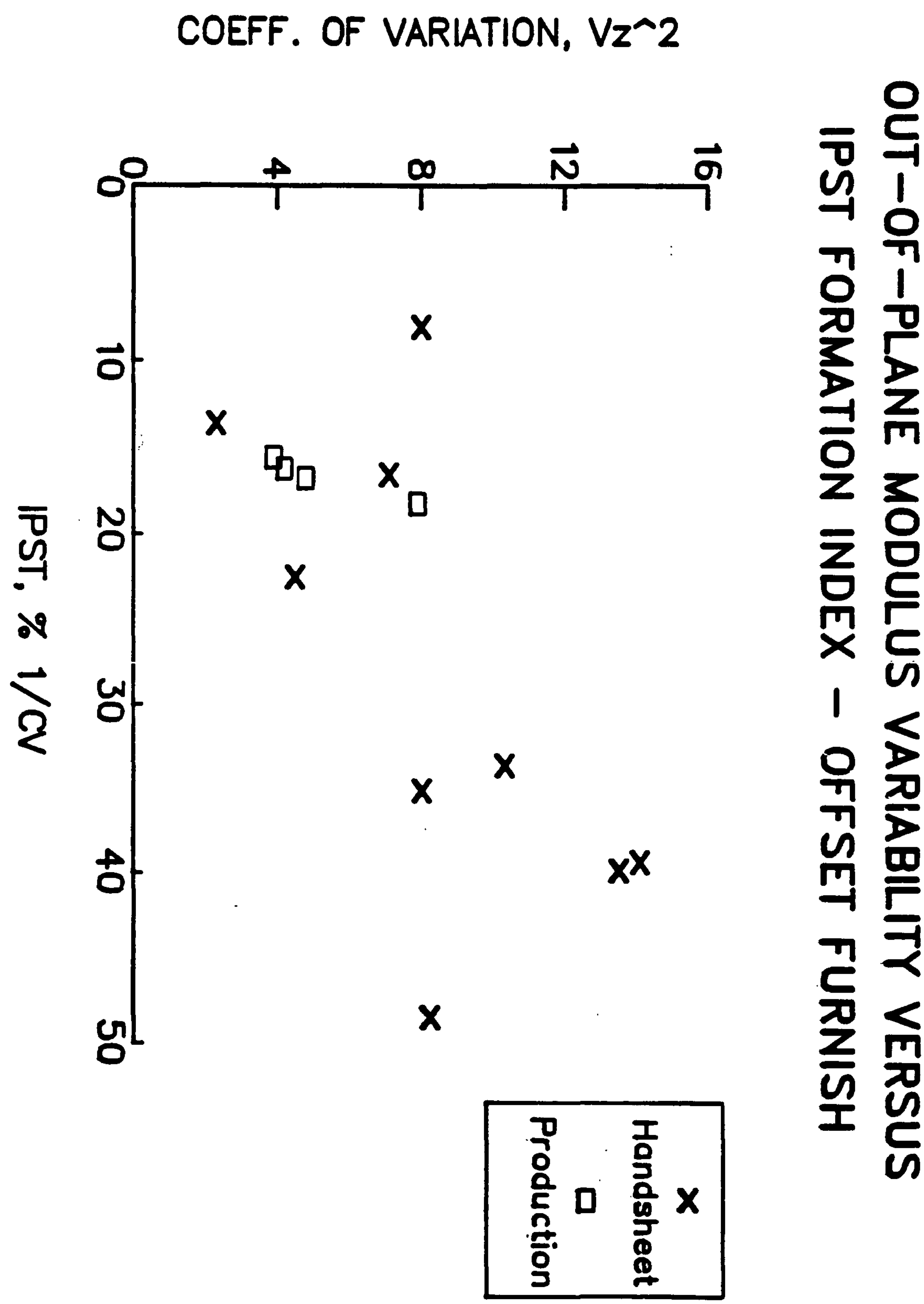

CALIPER VARIABILITY VERSUS
VISUAL RANKING – OFFSET FURNISH
% CV CALIPER
0
1
2
3
4
5
6
7
0
5
10
15
20
25
VISUAL RANKING
X Handsheet
□ Production

CALIPER VARIABILITY VERSUS IPST FORMATION INDEX – OFFSET FURNISH



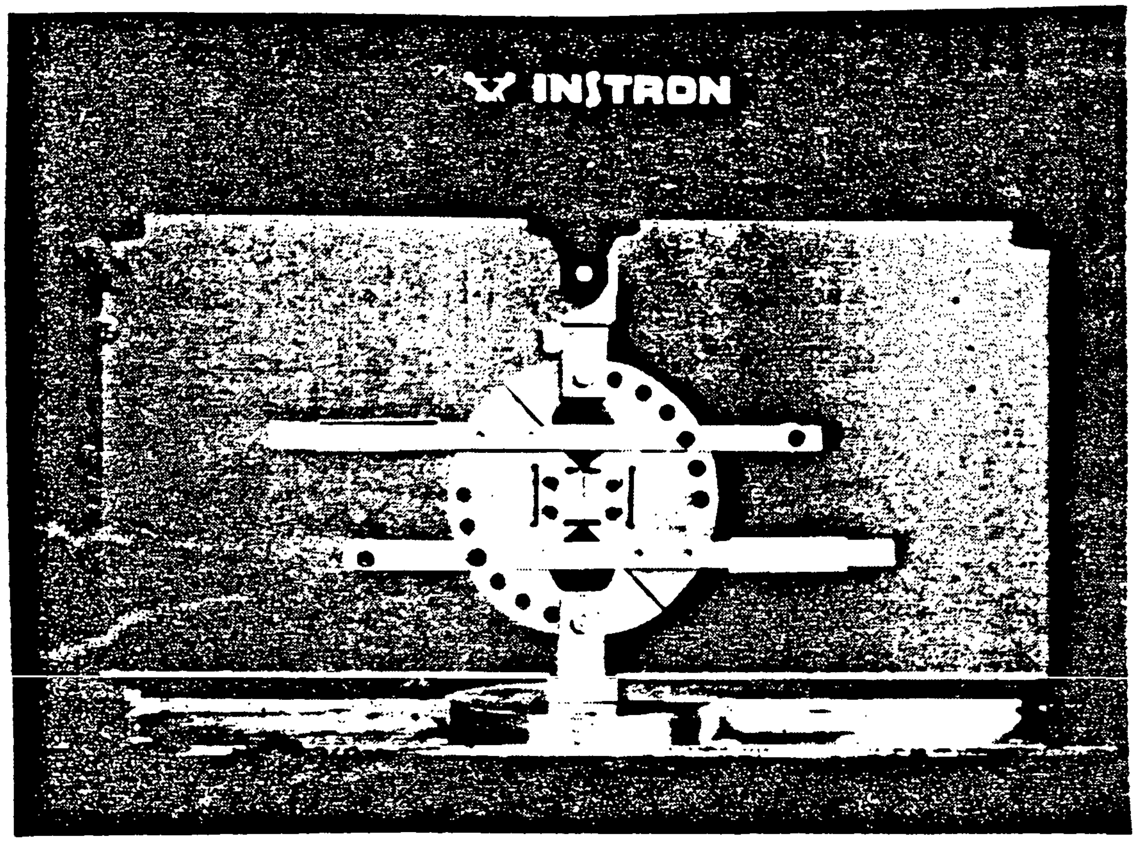

OUT-OF-PLANE MODULUS VERSUS
IPST FORMATION INDEX - OFFSET FURNISH
Vz^2, (km/sec)^2
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
IPST, % 1/CV
X Handsheet
□ Production

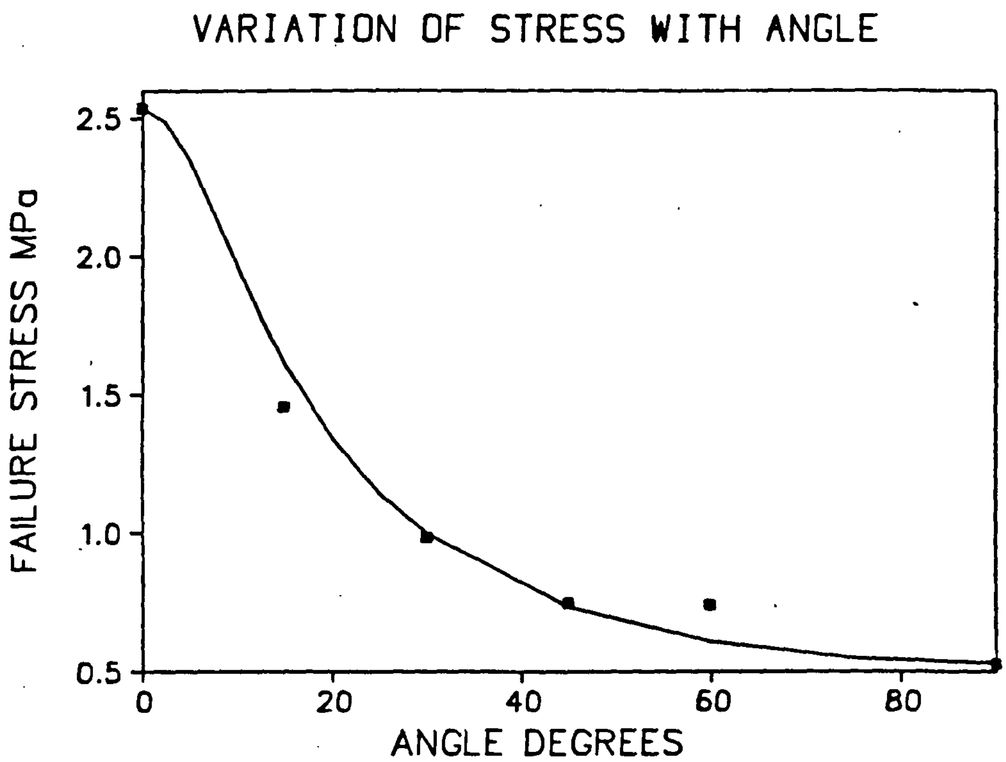

OUT—OF—PLANE MODULUS VERSUS
IPST APPARENT DENSITY — OFFSET FURNISH
Vz^2, (km/sec)^2
0
0.05
0.1
0.15
0.2
0.25
0.70
0.72
0.74
0.76
0.78
0.80
0.82
APPARENT DENSITY, g/cm^3
Handsheet
Production

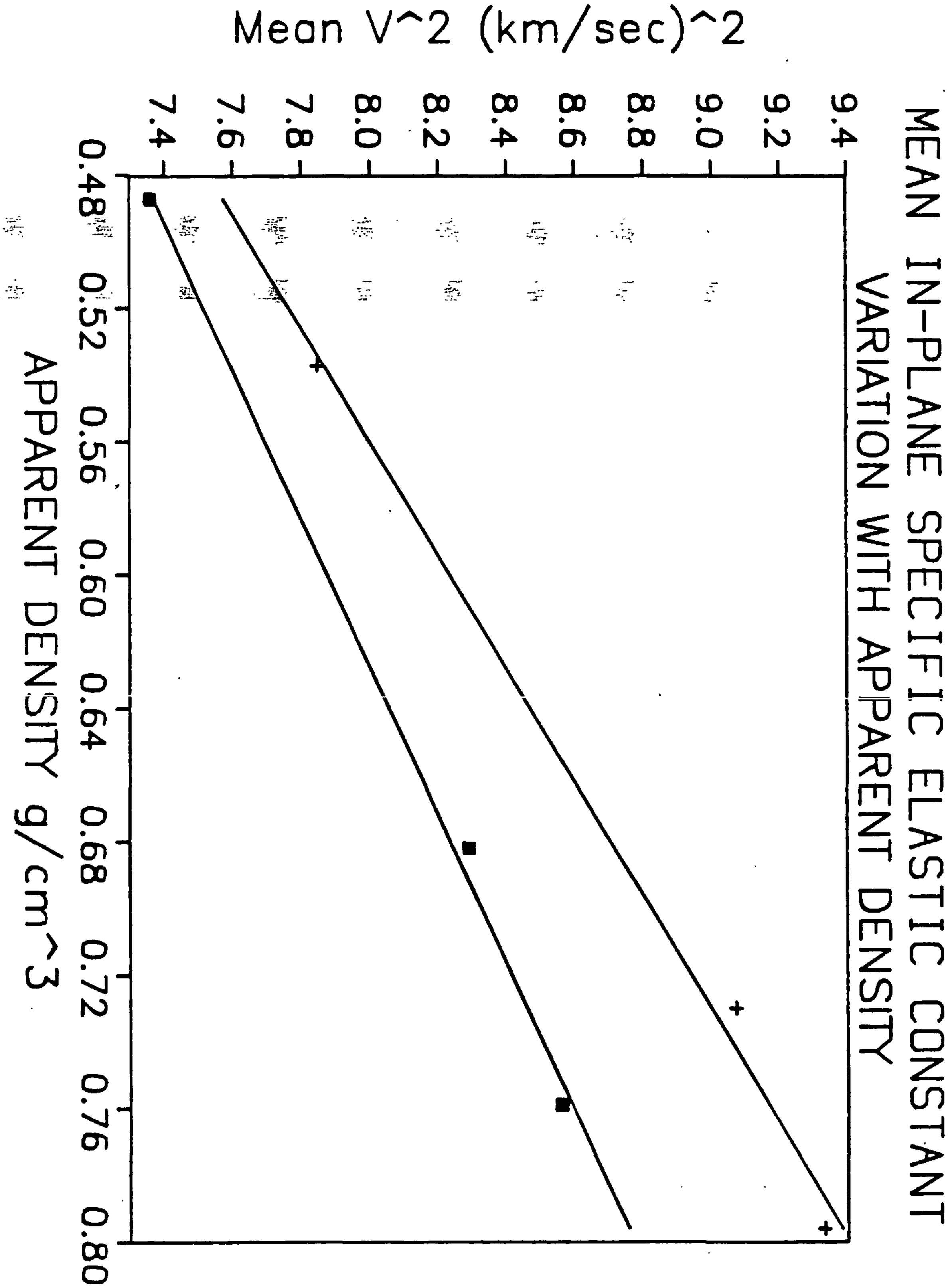

OUT-OF-PLANE MODULUS VARIABILITY VERSUS
IPST FORMATION INDEX - OFFSET FURNISH
COEFF. OF VARIATION, Vz^2
0
4
8
12
16
0
10
20
30
40
50
IPST, % 1/CV
Handsheet
Production

COMBINED STRESS MEASUREMENTS

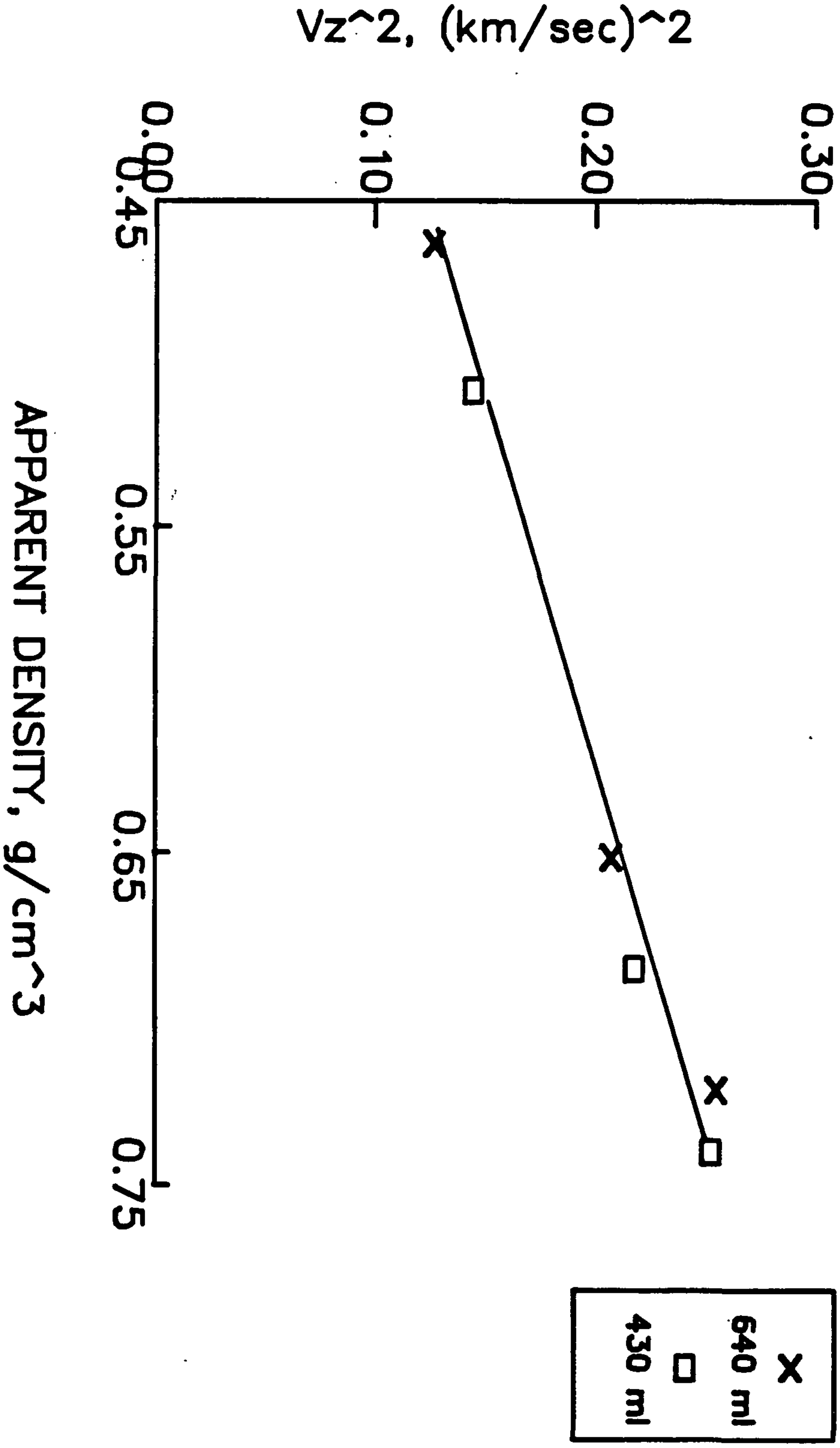
* Corrugating
* Calendering
* Adhesive Joints
* Paper Tubes

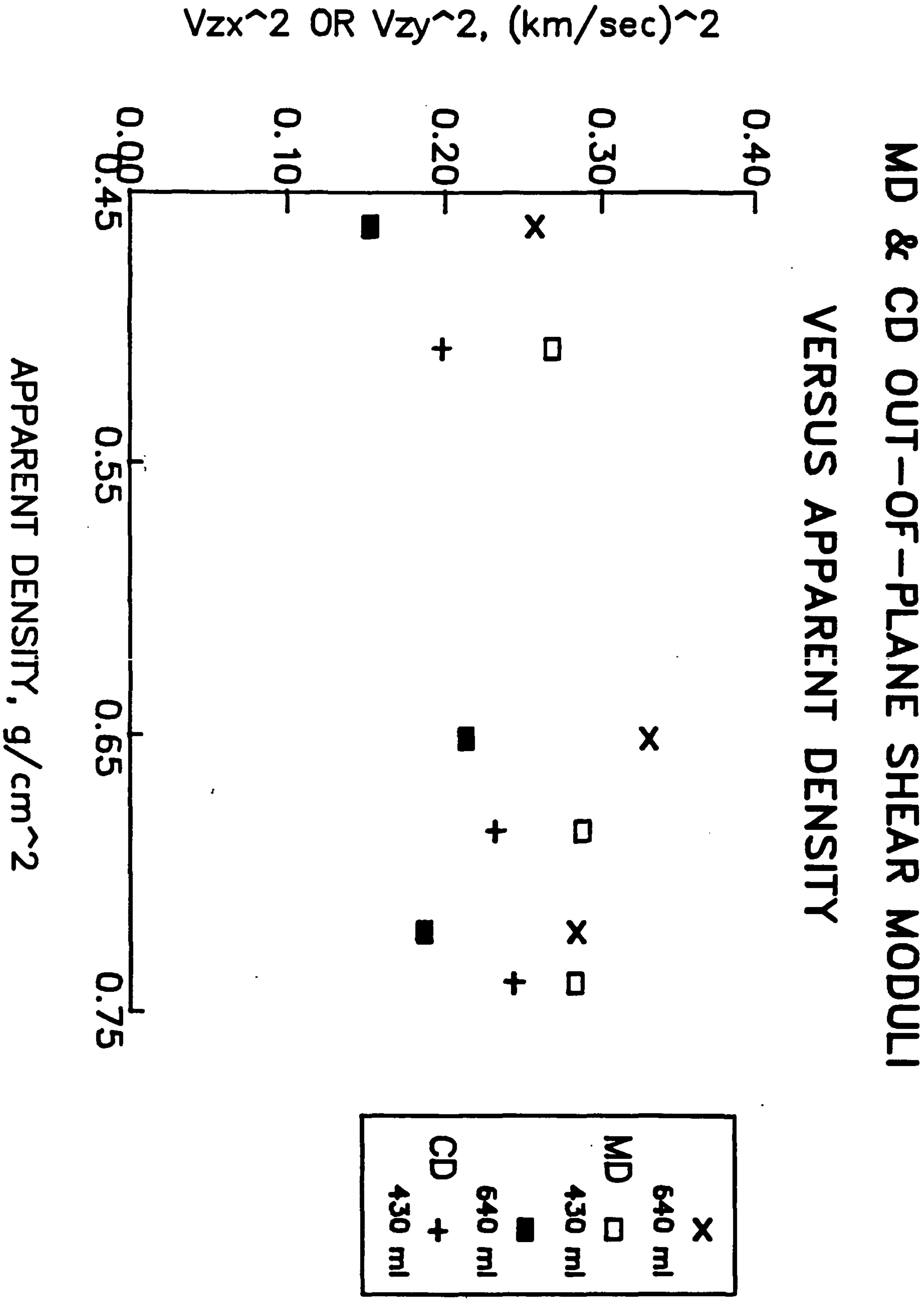

INSTRON


VARIATION OF STRESS WITH ANGLE
FAILURE STRESS MPa
2.5
2.0
1.5
1.0
0.5
0
20
40
60
80
ANGLE DEGREES


MEAN IN-PLANE SPECIFIC ELASTIC CONSTANT
VARIATION WITH APPARENT DENSITY
Mean V^2 (km/sec)^2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
8.8
9.0
9.2
9.4
0.48
0.52
0.56
0.60
0.64
0.68
0.72
0.76
0.80
APPARENT DENSITY g/cm^3

LONGITUDINAL OUT-OF-PLANE MODULUS VERSUS APPARENT DENSITY




MD & CD OUT–OF–PLANE SHEAR MODULI
VERSUS APPARENT DENSITY
Vzx^2 OR Vzy^2, (km/sec)^2
0.00
0.10
0.20
0.30
0.40
0.45
0.55
0.65
0.75
APPARENT DENSITY, g/cm^2
MD
640 ml
430 ml
CD
640 ml
430 ml

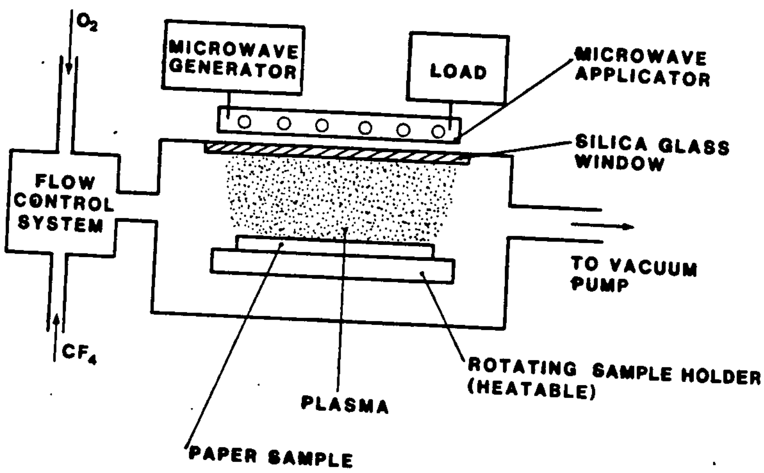
INTERNAL STRESSES IN PAPER AND BOARD

* Elastic Properties
* Strength Properties
* Dimensional Stability
* Curl

LAYER REMOVAL TECHNIQUE FOR MEASURING RESIDUAL STRESSES

Layer Removal Techniques:

1. Surface Grinding
2. Excimer Laser
3. Plasma Etching
4. Ion Milling



O_2
MICROWAVE GENERATOR
LOAD
MICROWAVE APPLICATOR
SILICA GLASS WINDOW
FLOW CONTROL SYSTEM
TO VACUUM PUMP
CF_4
ROTATING SAMPLE HOLDER (HEATABLE)
PLASMA
PAPER SAMPLE

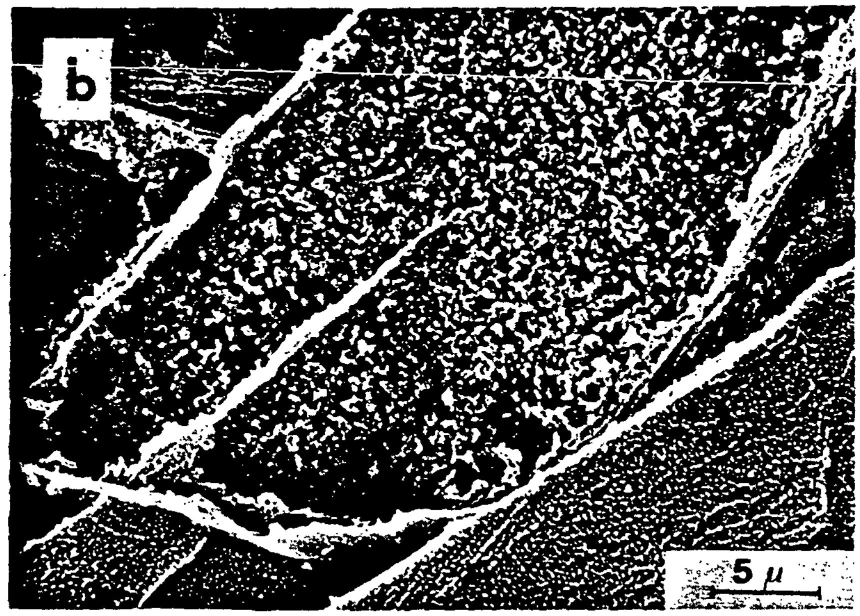


Fig. 12. SEM micrographs of lumen-loaded fibers after plasma-etching, showing TiO_2 particles inside the lumen.

STUDENT RELATED WORK

A190 Research Projects

1. "Non–destructive Measurement of Aging" – Andrew Kao
2. "The Effect of Internal Stresses on the Modification of Paper Properties by Calendering" – Renee Ebert

A490 Doctoral Research

1. "Strength Development through Refining and Wet Pressing" – Thomas Bither

INTERNAL STRENGTH ENHANCEMENT

SLIDE MATERIAL

FOR

PROJECT 3526

TO THE

PAPER PROPERTIES AND USES

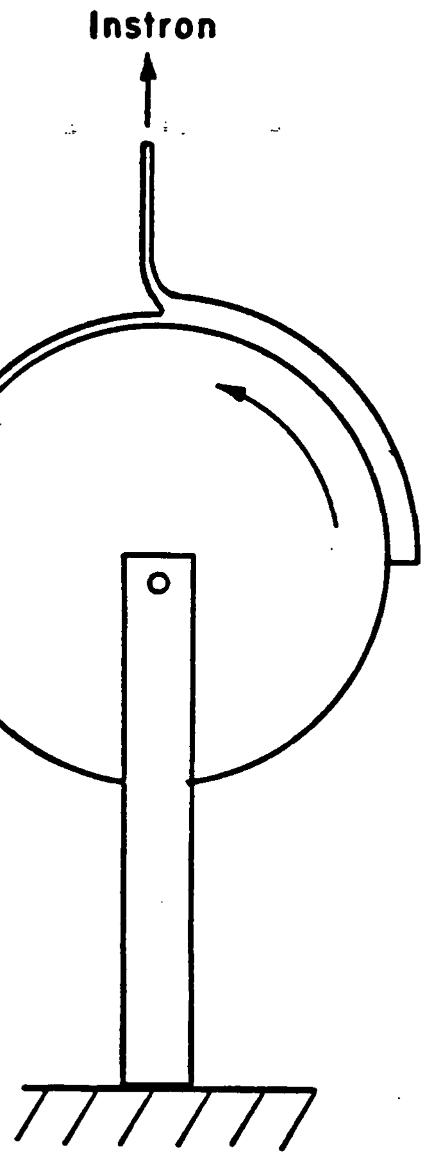
PROJECT ADVISORY COMMITTEE

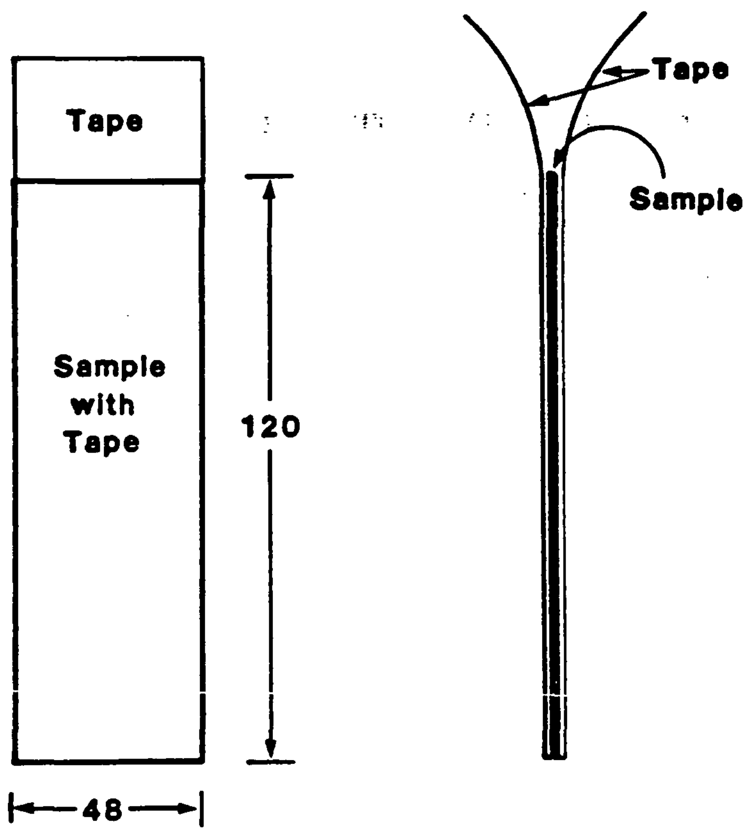
March 21, 1990

INTERNAL STRENGTH ENHANCEMENT

PROJECT 3526

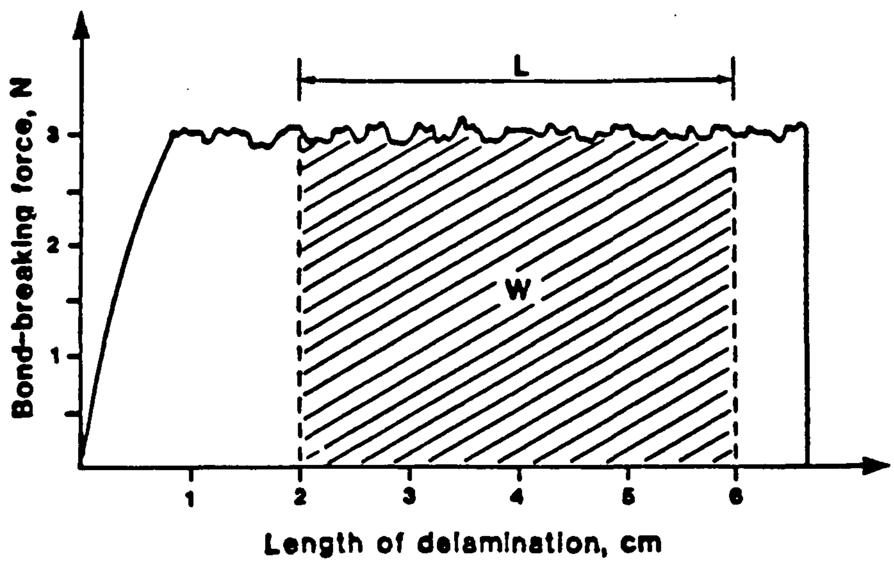
ROBERT A. STRATTON


Instron



FRONT VIEW

SIDE VIEW


L
W
Bond-breaking force, N
1
2
3
1
2
3
4
5
6
Length of delamination, cm

PULP PROPERTIES

YIELD, %	KAPPA NO.
47.5	34.7
51.2	42.2
60.4	116.0
80.7	167.0

PULPS

YIELD, %	FREENESS, mL CSF			
47	685	600	350	200
52	740	600	340	200
60	750	600	350	200
80	780	600	340	200

FACTORS DETERMINING SHEET STRENGTH

1) FIBER PROPERTIES - STRENGTH AND LENGTH
2) BOND STRENGTH
3) BONDED AREA
4) FIBER AND BOND DISTRIBUTION

RELATIVE BONDED AREA

$$RBA = (A_u - A_s)/A_u$$

A_u = AREA OF COMPLETELY UNBONDED SHEET

A_s = AREA OF SAMPLE SHEET

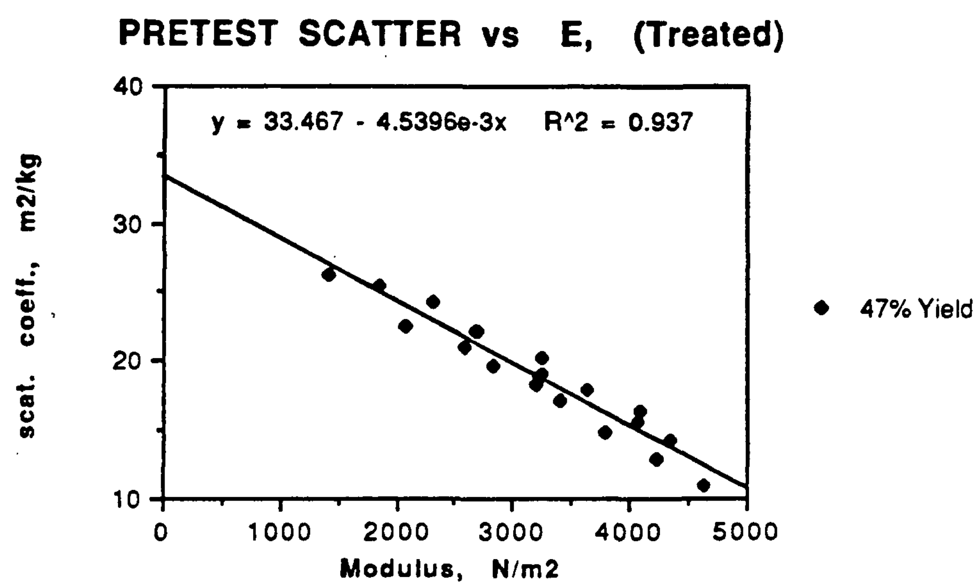
ASSUMPTION: $A = kS$

RELATIVE BONDED AREA

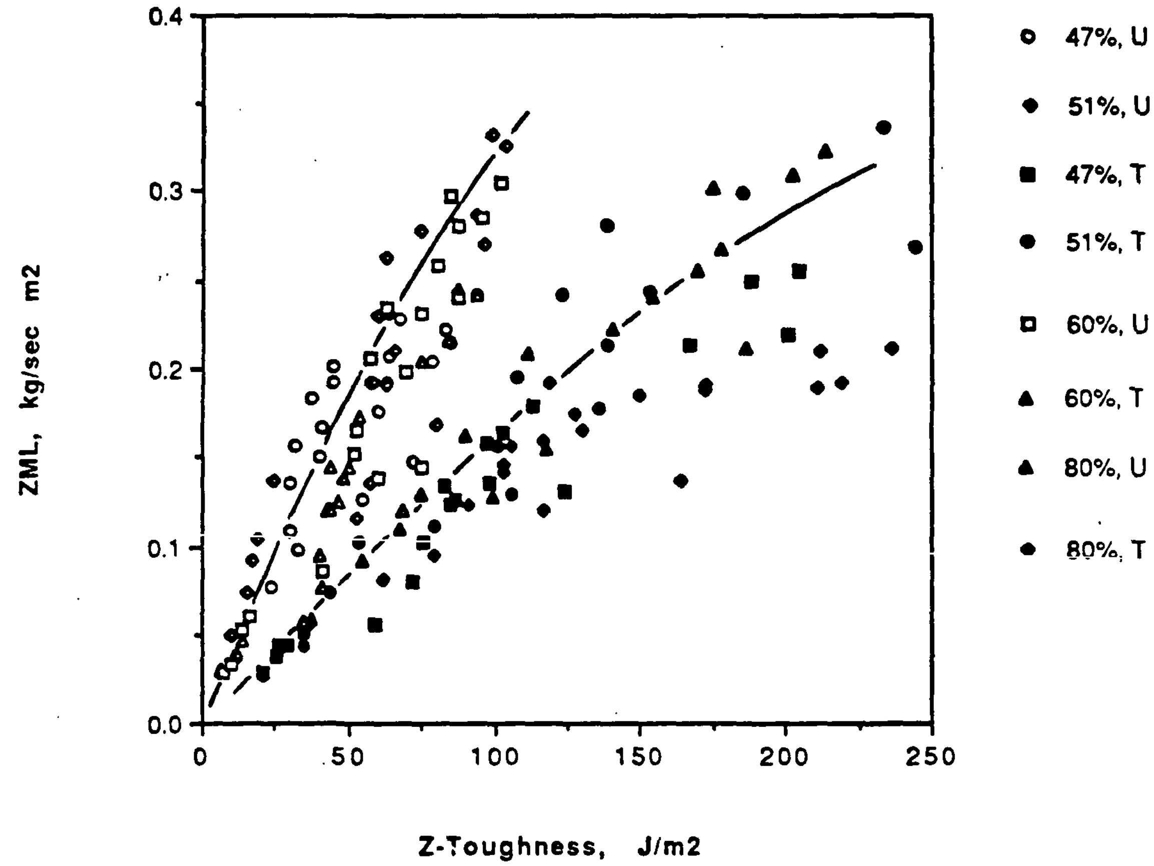
$$RBA = (S_o - S)/S_o$$

S_o = Scattering from completely unbonded sheet

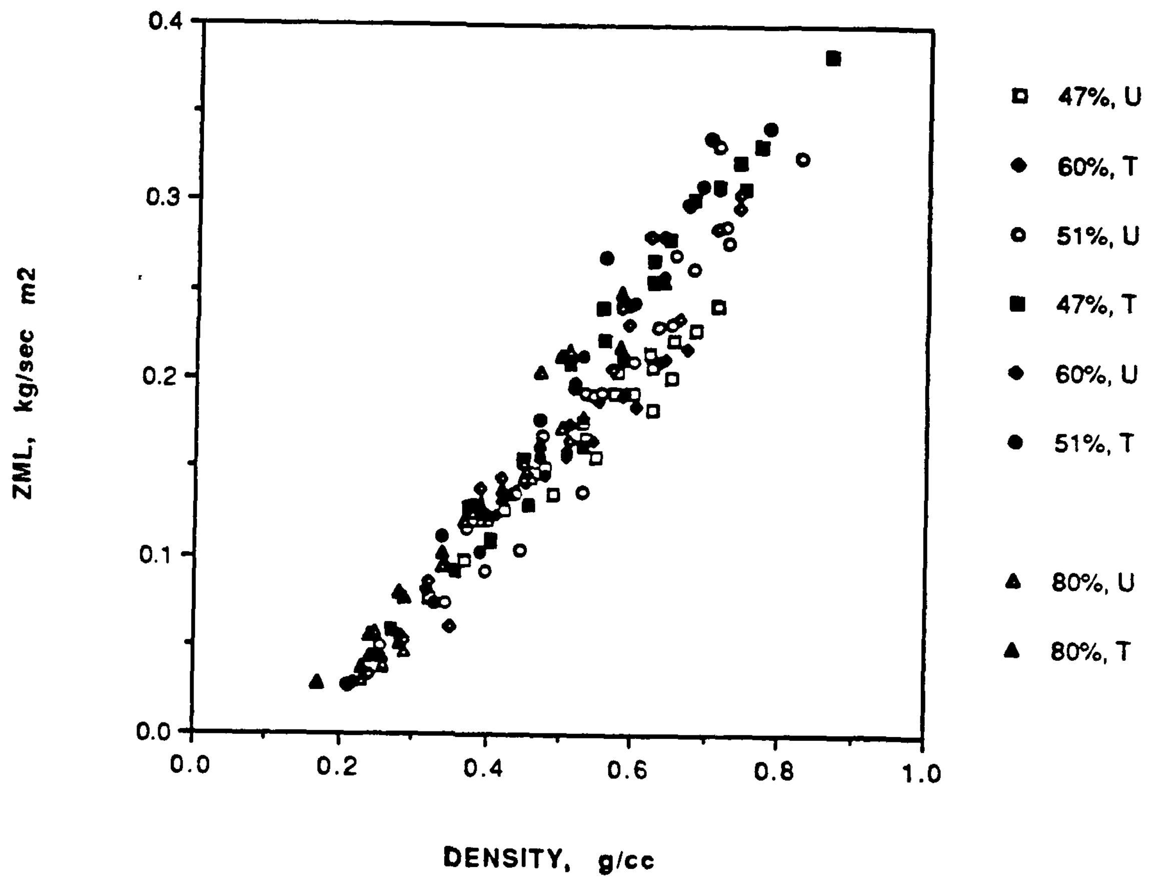
S = Scattering of sample sheet


PRETEST SCATTER vs E, (Treated)
y = 33.467 - 4.5396e-3x R^2 = 0.937
40
30
20
10
0
1000
2000
3000
4000
5000
scat. coeff., m2/kg
Modulus, N/m2
47% Yield

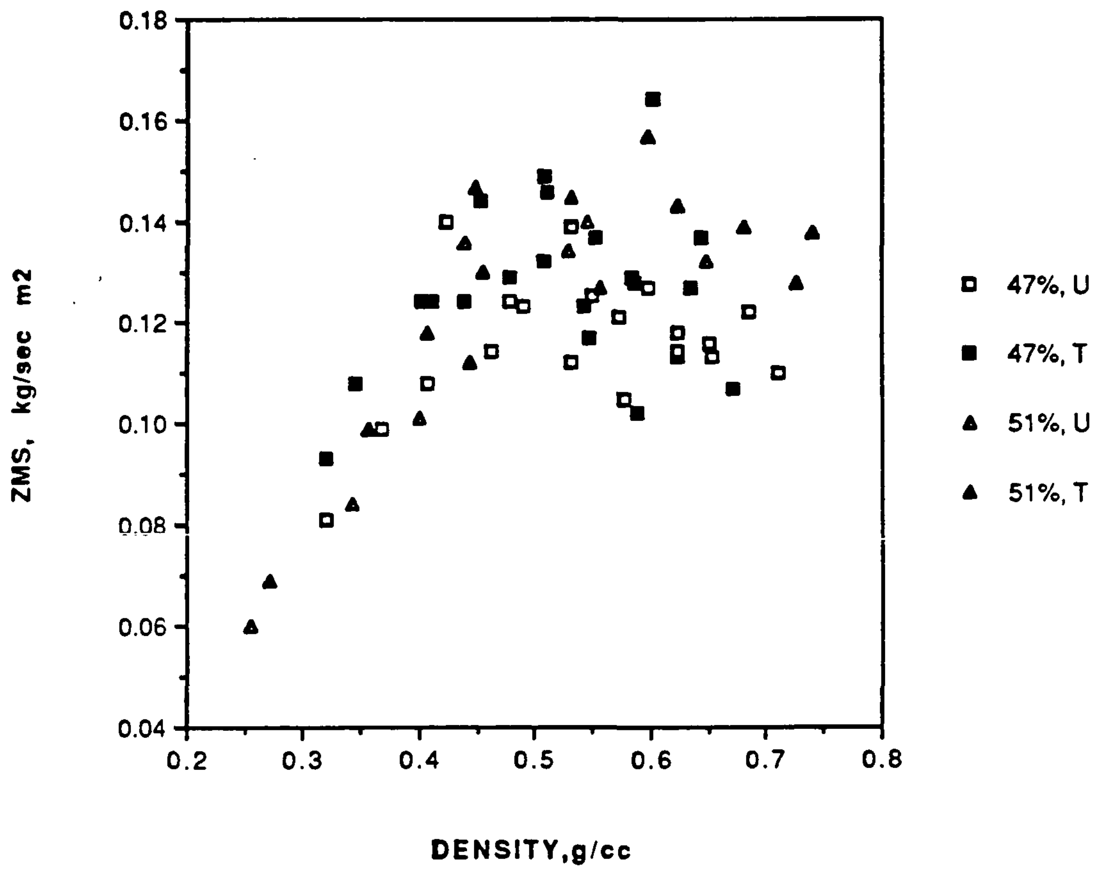
OUT OF PLANE LONG. ACOUST. IMPEDANCE

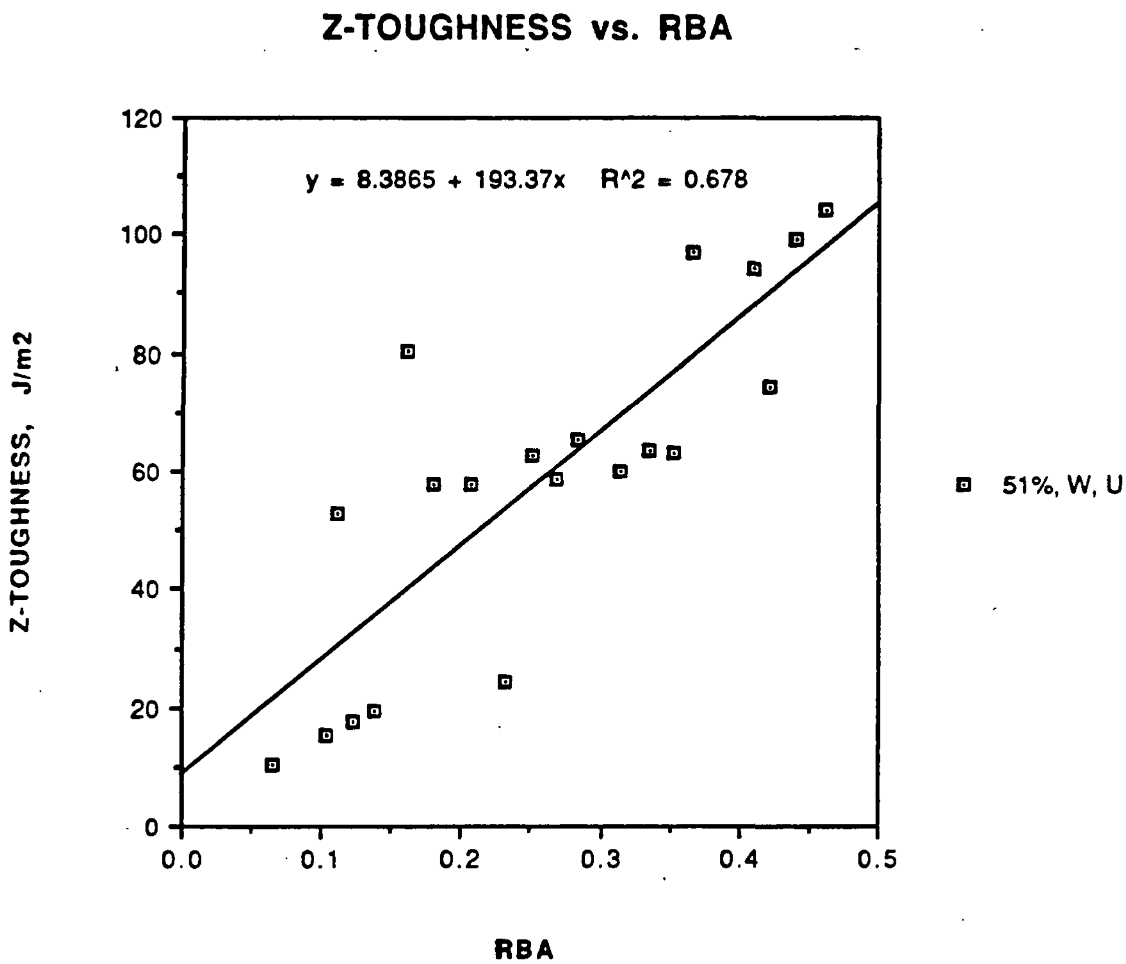


OUT OF PLANE LONG. ACOUST. IMPEDANCE



OUT OF PLANE SHEAR ACOUST. IMPEDANCE

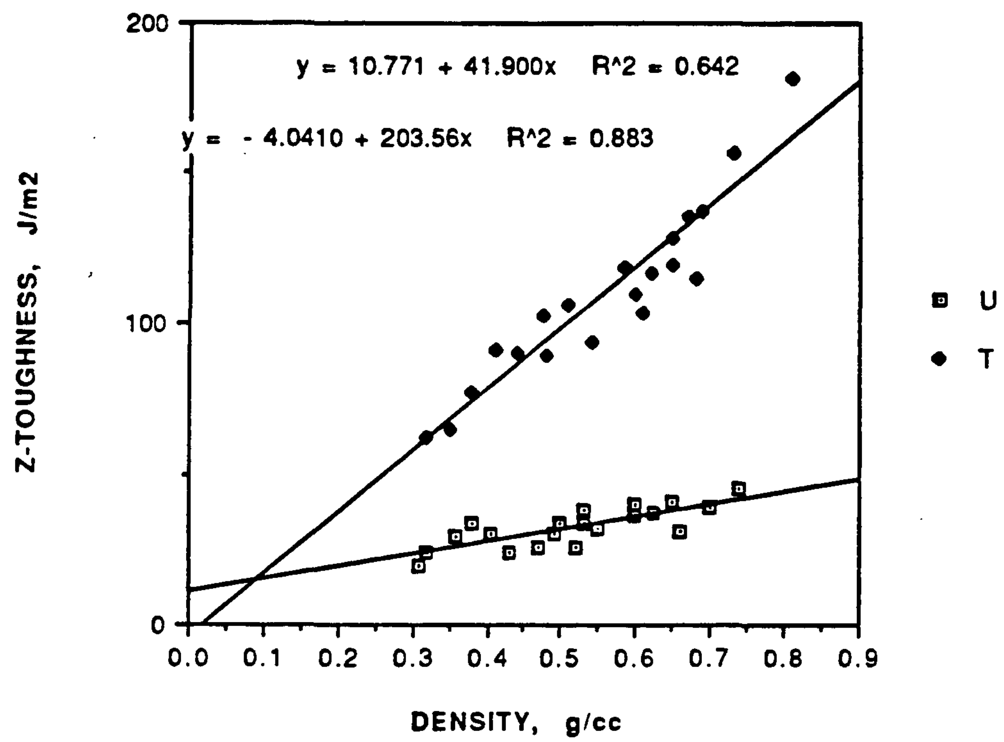



Z-TOUGHNESS vs. RBA
y = 8.3865 + 193.37x R^2 = 0.678
120
100
80
60
40
20
0
0.0
0.1
0.2
0.3
0.4
0.5
Z-TOUGHNESS, J/m2
RBA
51%, W, U

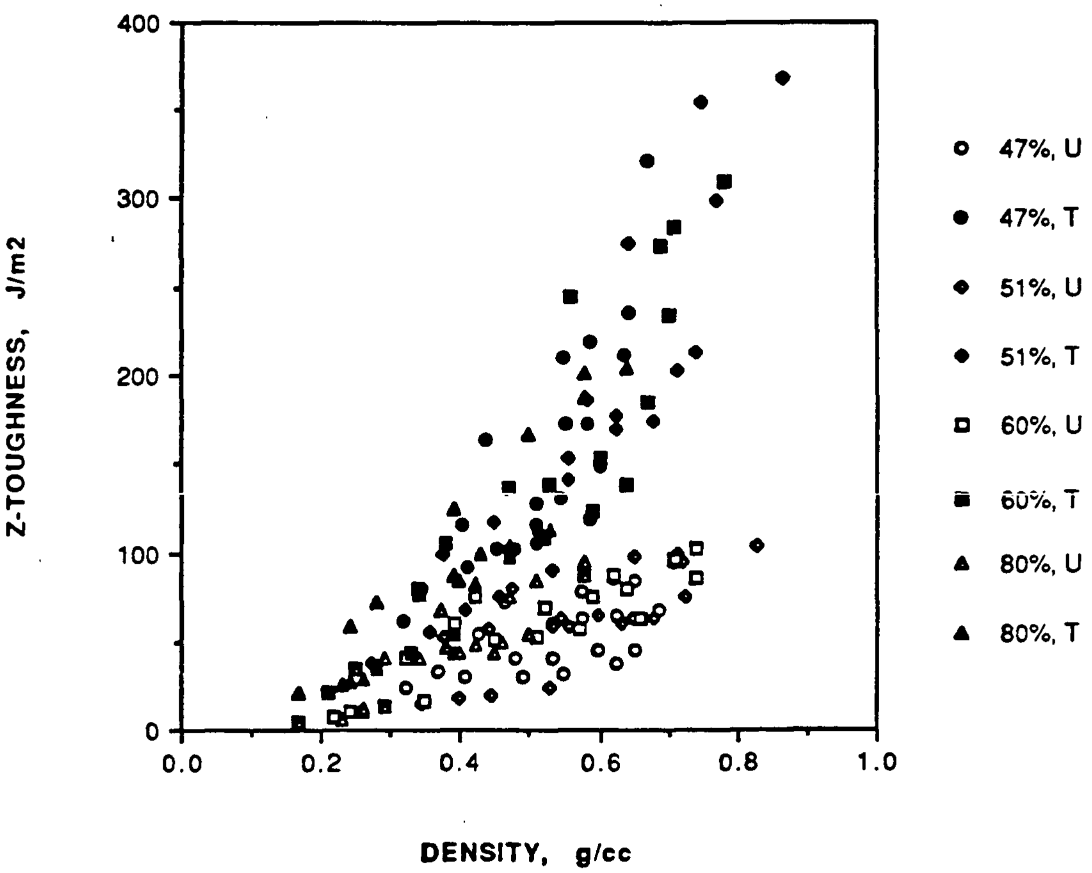
DEPENDENCE OF Z-TOUGHNESS ON RBA

PULP	TREATMENT	dG_Z/d RBA, J/m^2 AVERAGE	S.D.
Whole	No	170	20
Whole	Yes	530	40
Class.	No	50	10
Class.	Yes	230	30

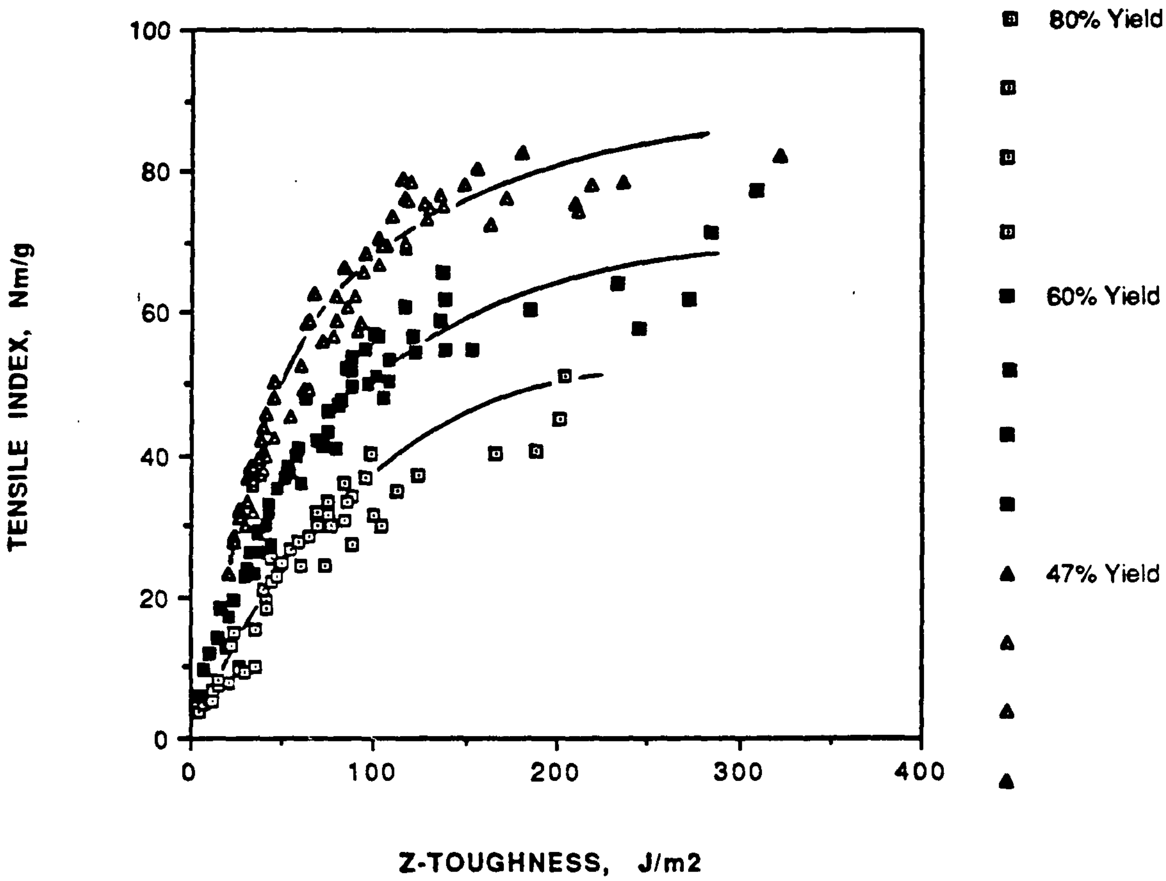
Z-TOUGHNESS vs. DENSITY, 47% YIELD, C



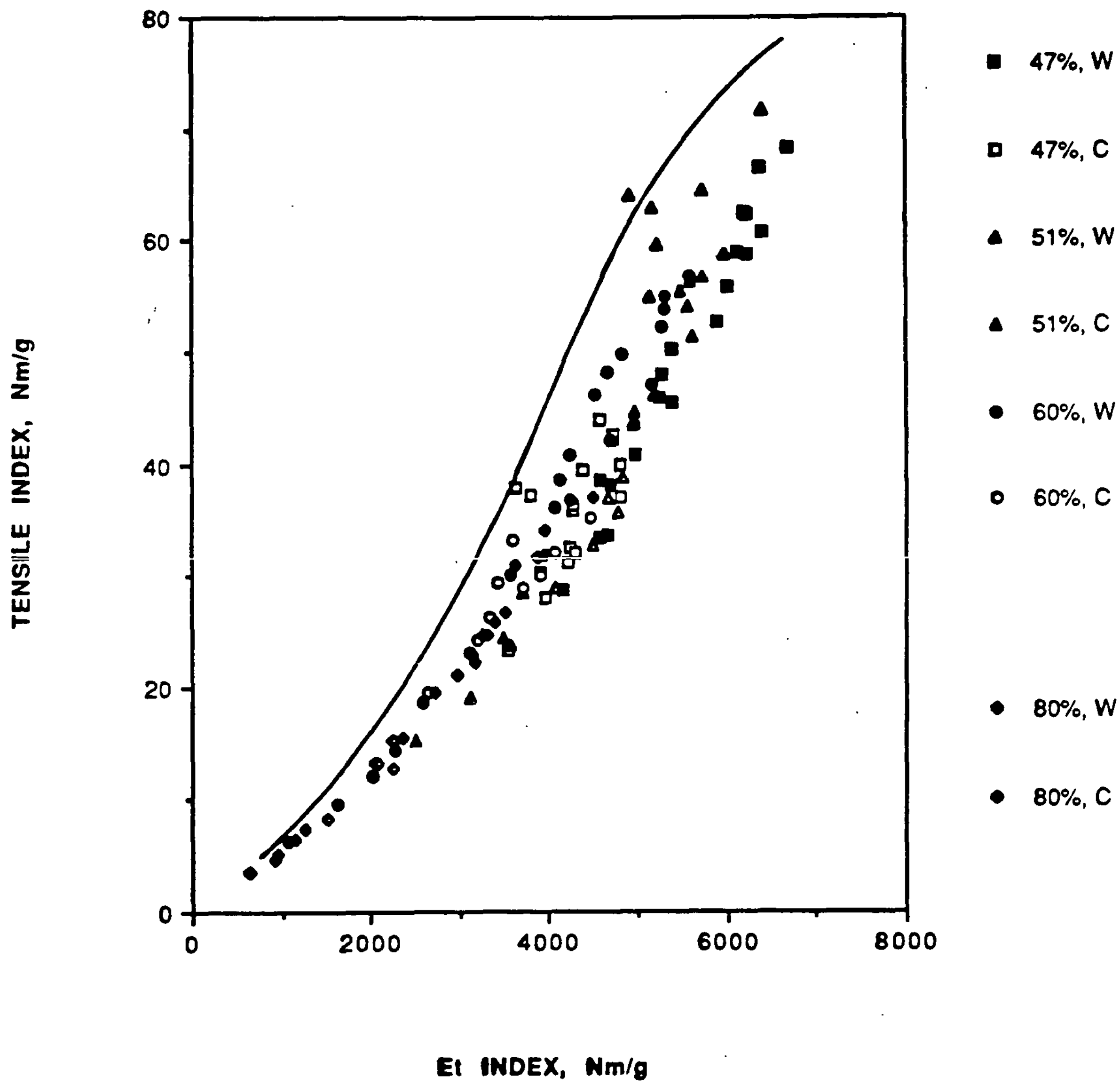
Z-TOUGHNESS vs. DENSITY

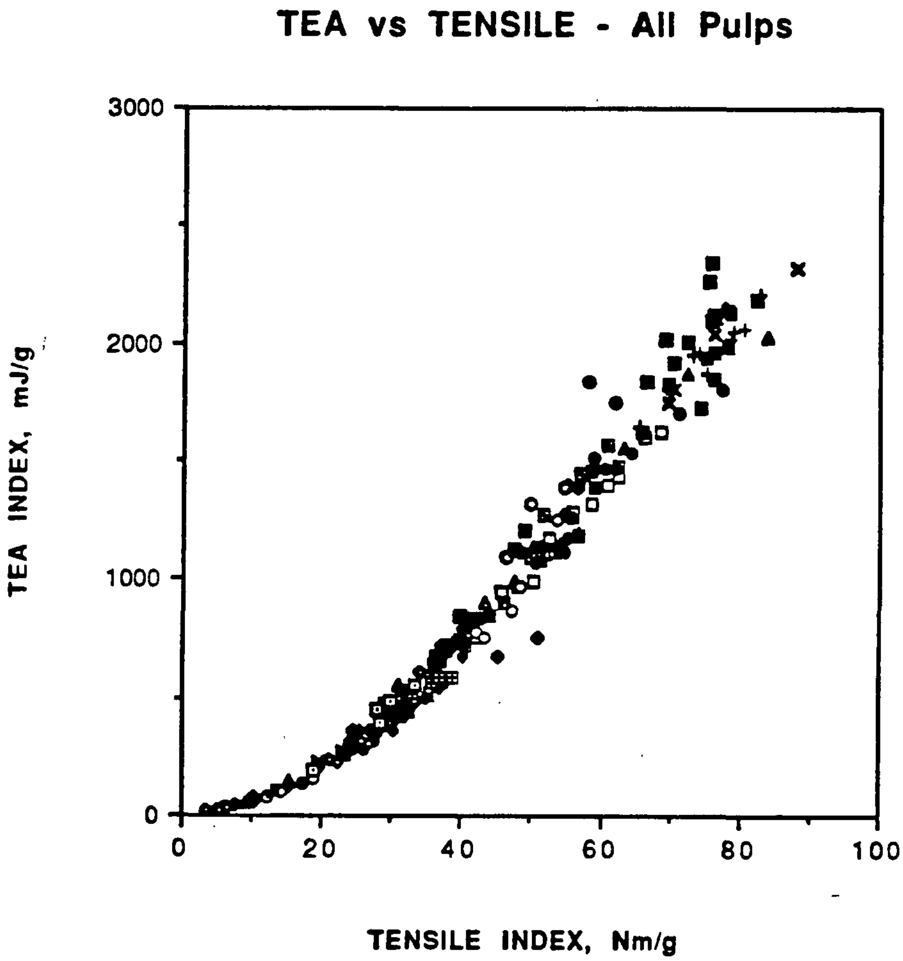


TENSILE INDEX vs. Z-TOUGHNESS

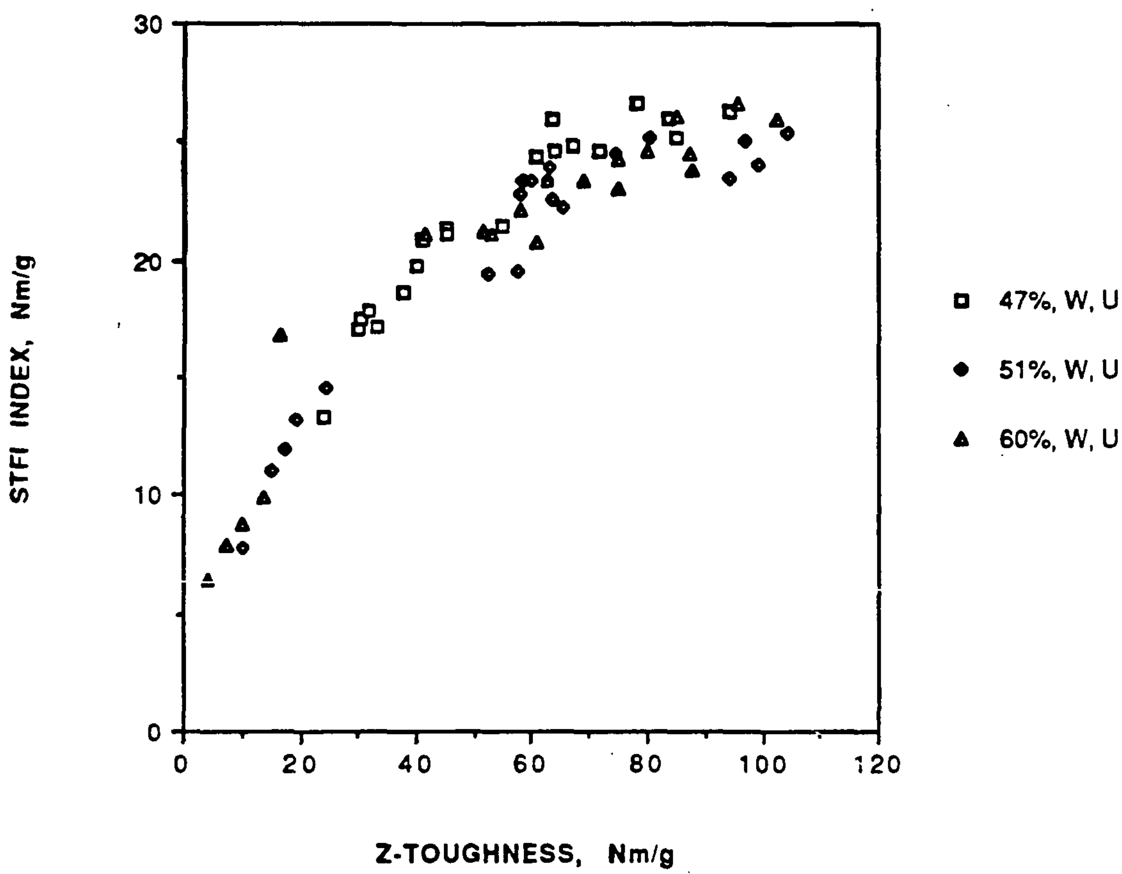


TENSILE STRENGTH vs. EXTENSIONAL STIFFNESS

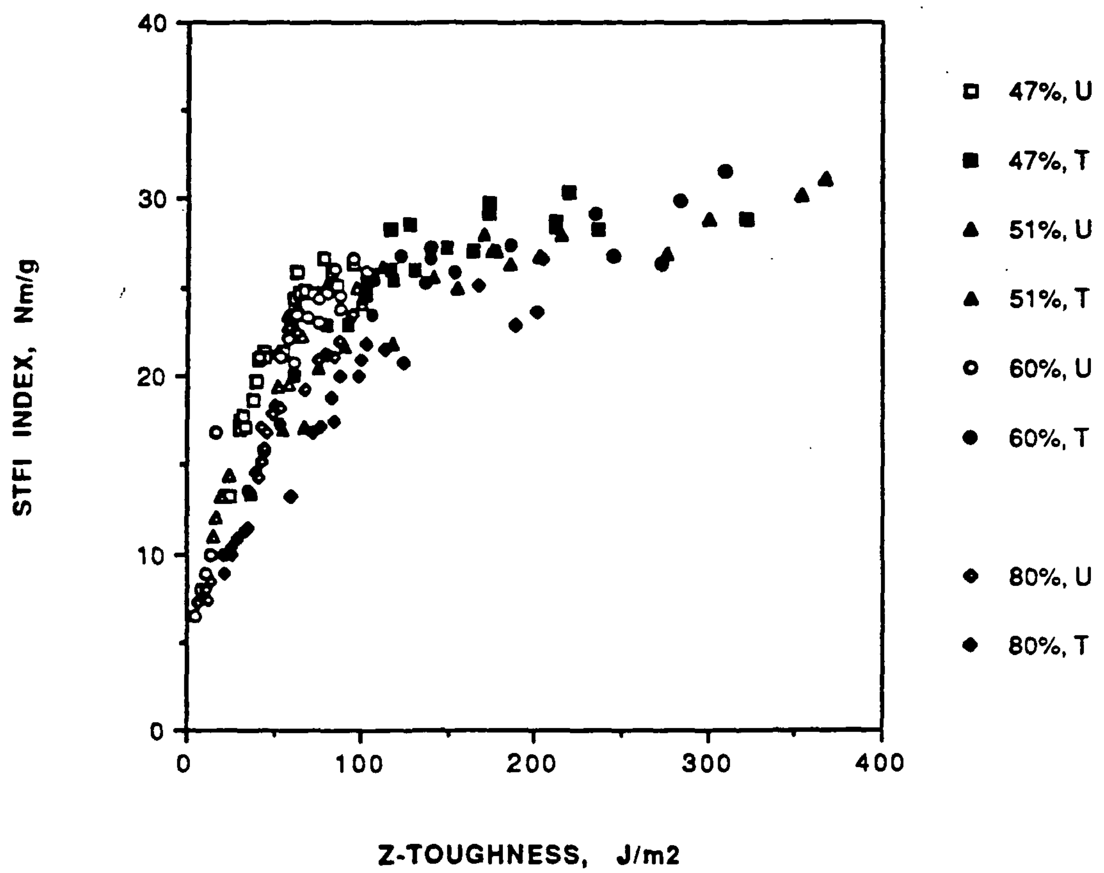


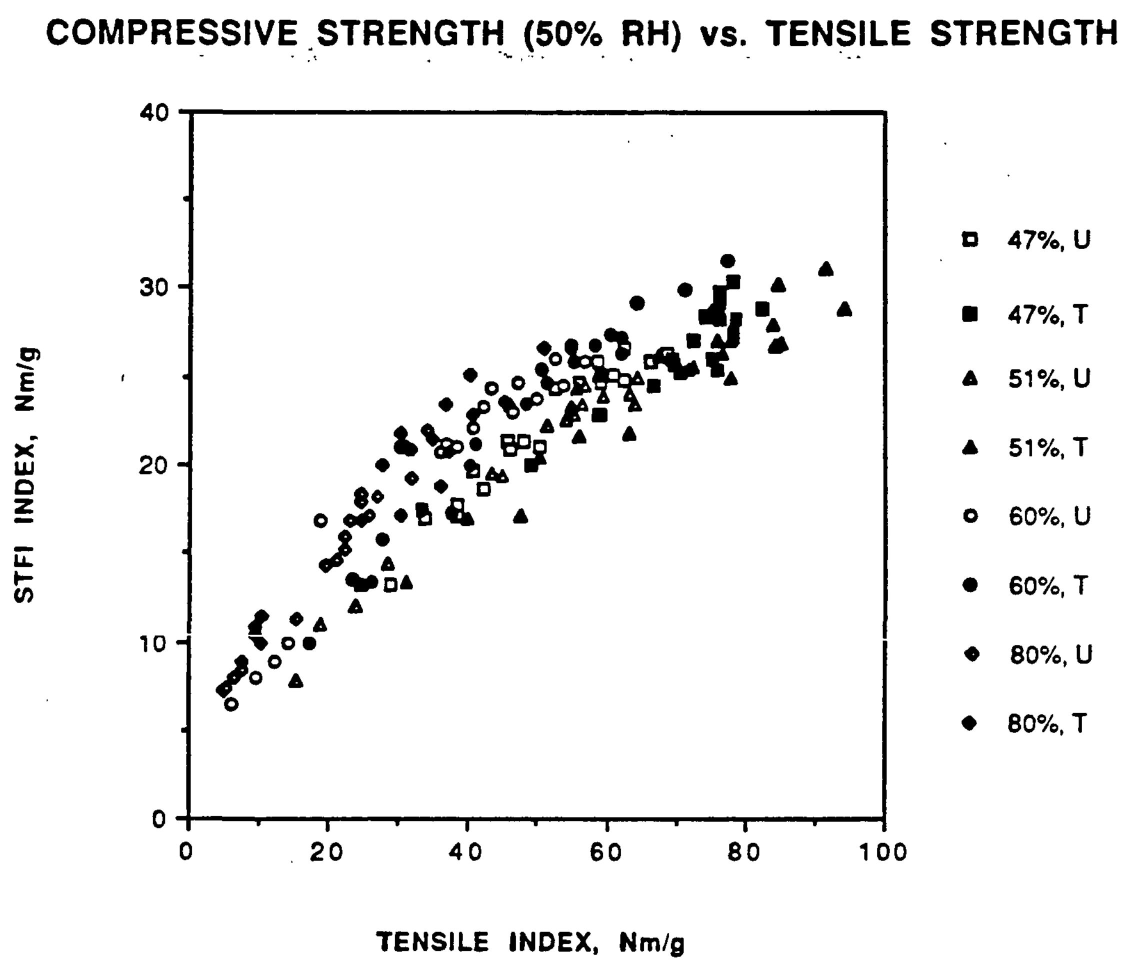

TEA vs TENSILE - All Pulps
TEA INDEX, mJ/g
TENSILE INDEX, Nm/g
3000
2000
1000
0
0
20
40
60
80
100

COMPRESSIVE STRENGTH vs. Z-TOUGHNESS, 50% RH

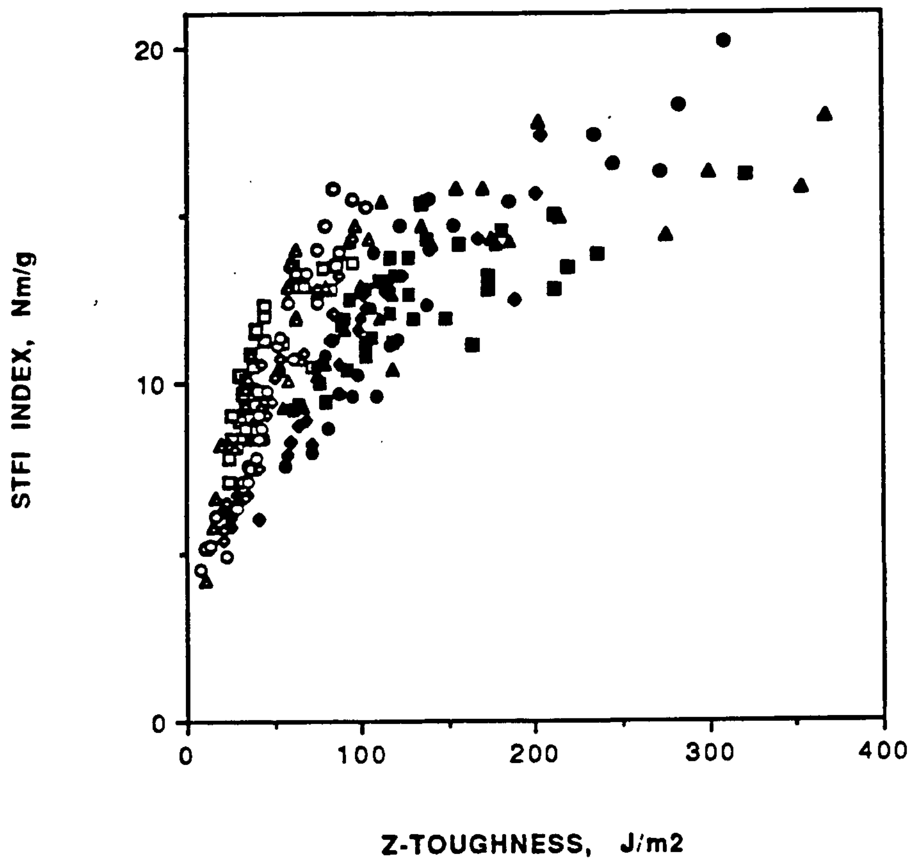


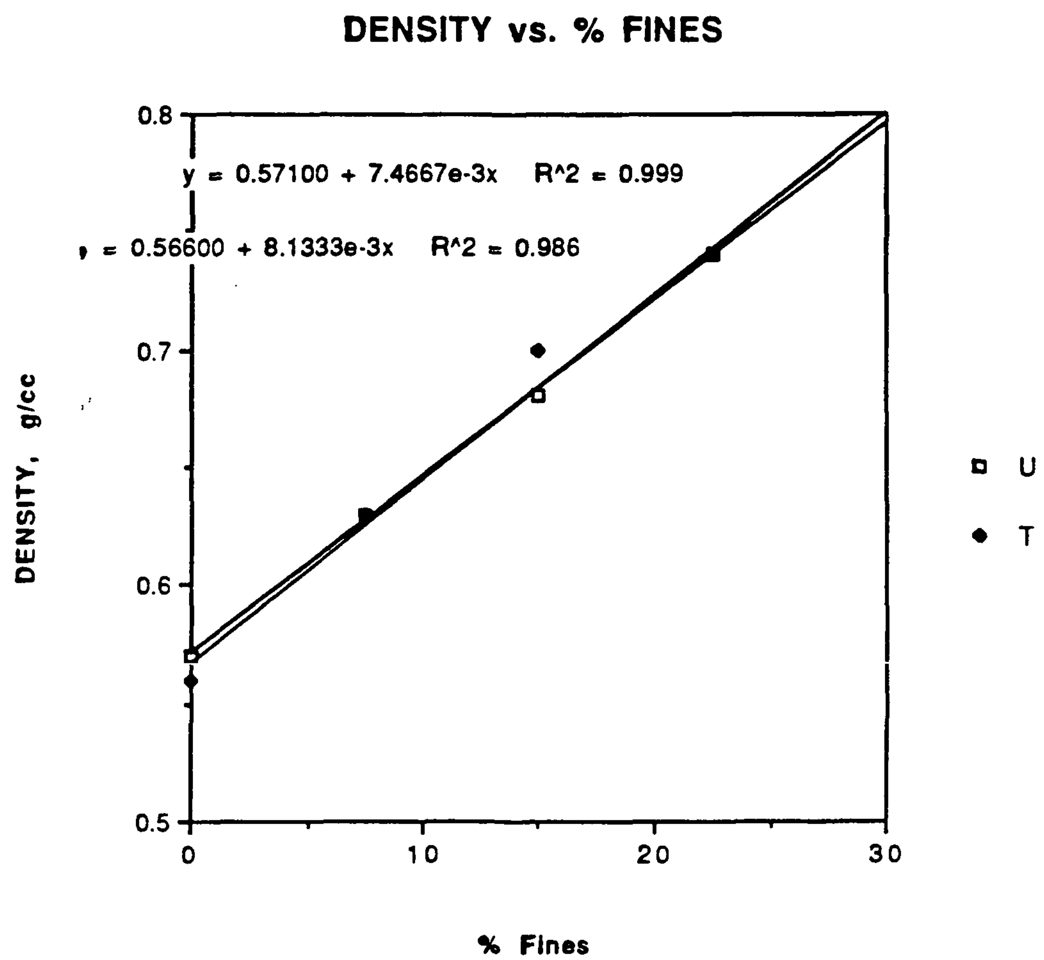
COMPRESSIVE STRENGTH (50% RH) vs. Z-TOUGHNESS

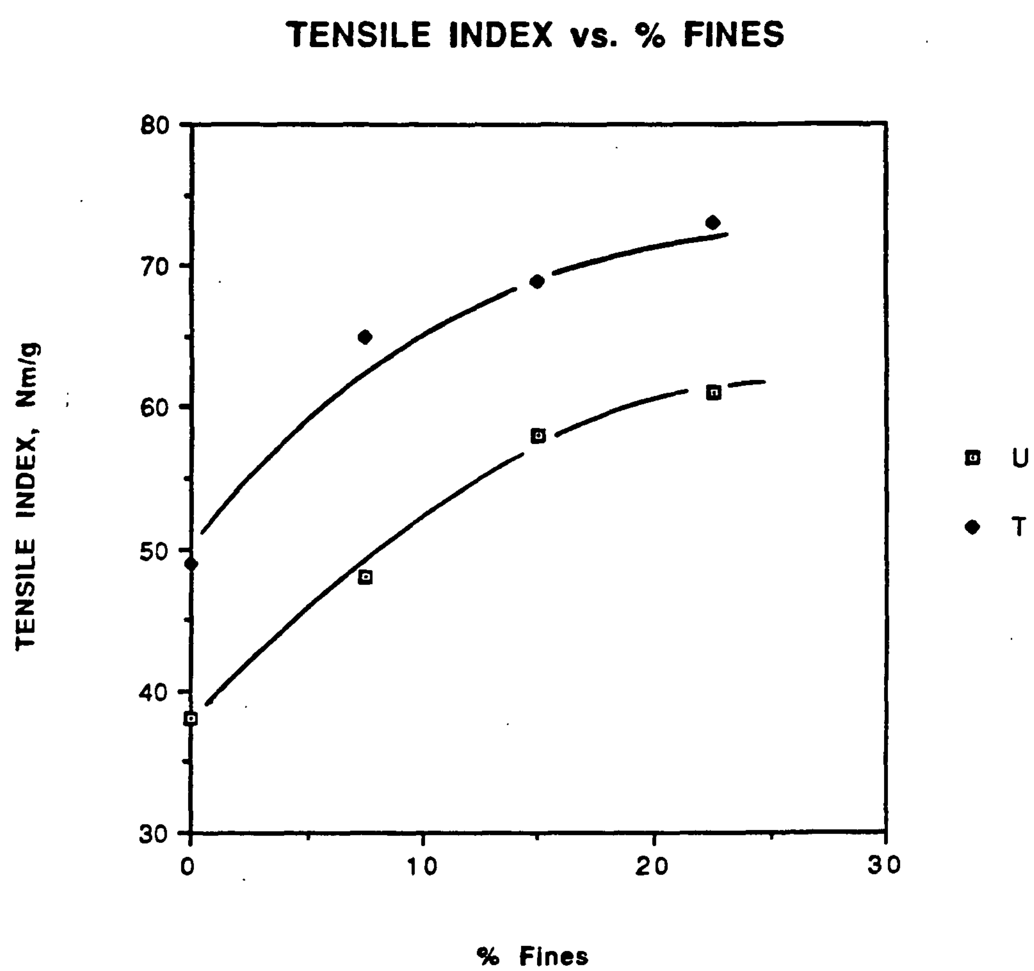


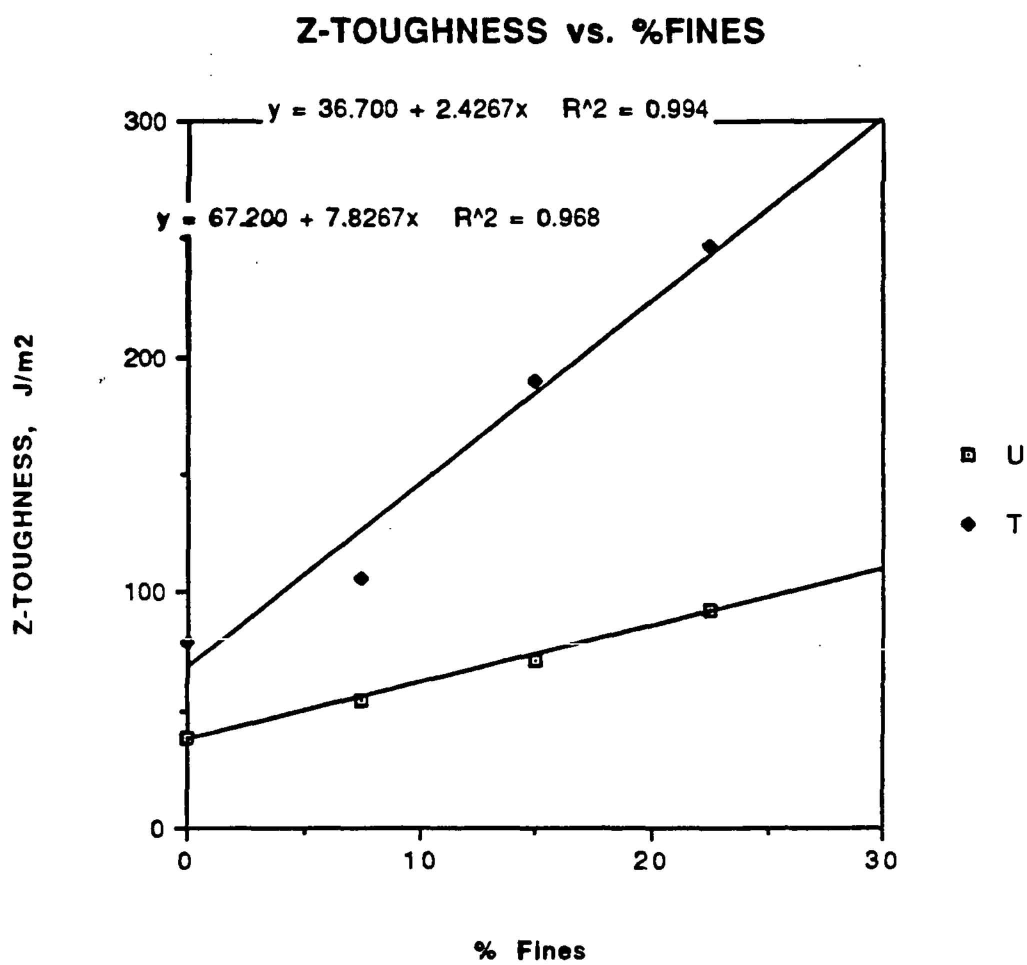

COMPRESSIVE STRENGTH (50% RH) vs. TENSILE STRENGTH
STFI INDEX, Nm/g
TENSILE INDEX, Nm/g
0
10
20
30
40
0
20
40
60
80
100
47%, U
47%, T
51%, U
51%, T
60%, U
60%, T
80%, U
80%, T

COMPRESSIVE STRENGTH (90% RH) VS. Z-TOUGHNESS

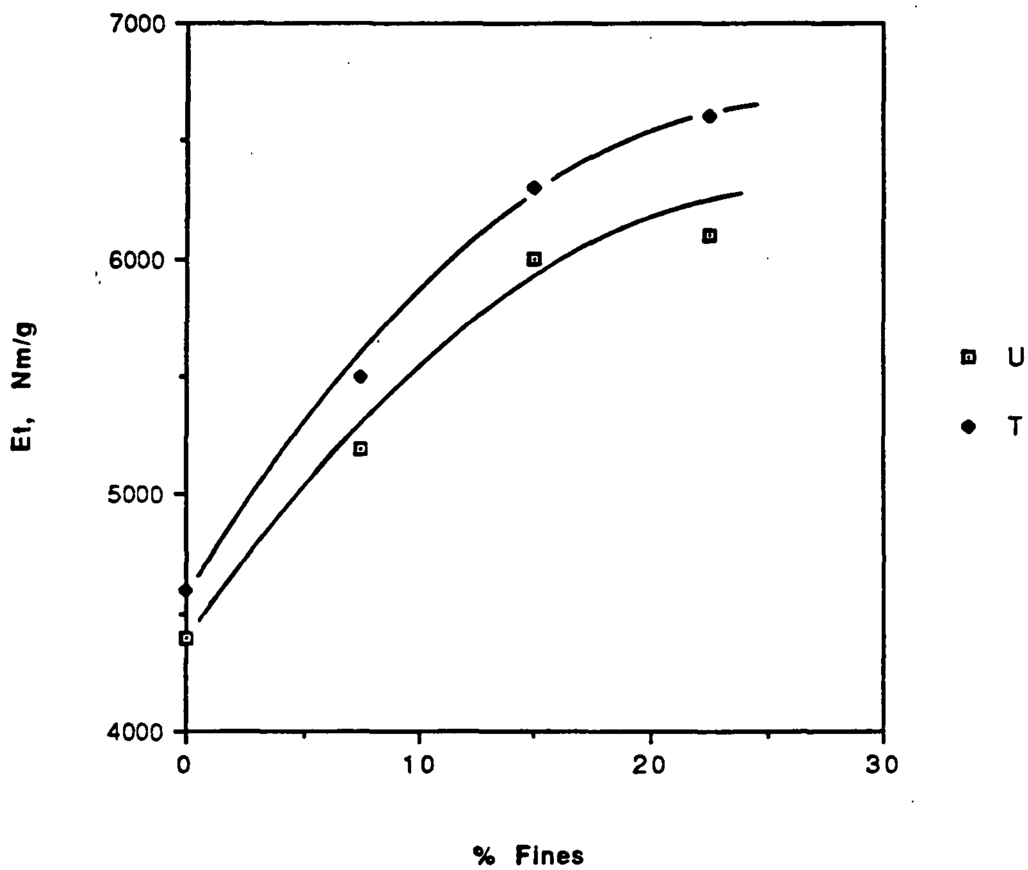



DENSITY vs. % FINES
y = 0.57100 + 7.4667e-3x R^2 = 0.999
y = 0.56600 + 8.1333e-3x R^2 = 0.986
0.8
0.7
0.6
0.5
0
10
20
30
DENSITY, g/cc
% Fines
U
T

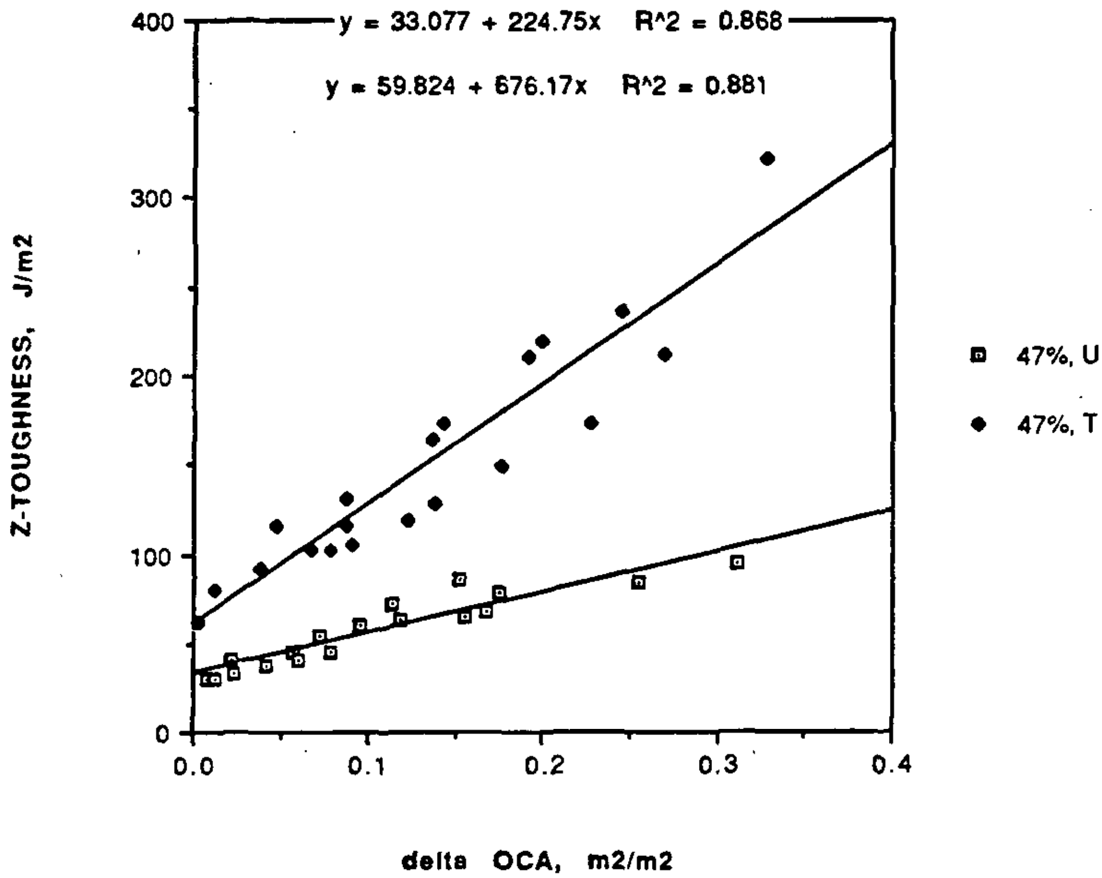

TENSILE INDEX vs. % FINES
80
70
60
50
40
30
0
10
20
30
TENSILE INDEX, Nm/g
% Fines
U
T


Z-TOUGHNESS vs. %FINES
y = 36.700 + 2.4267x R^2 = 0.994
y = 67.200 + 7.8267x R^2 = 0.968
300
200
100
0
0
10
20
30
Z-TOUGHNESS, J/m2
% Fines
U
T

EXTENSIONAL STIFFNESS vs. % FINES



DETERMINATION OF SPECIFIC Z-TOUGHNESS



SPECIFIC Z-TOUGHNESS

	SG_z, J/m^2	
YIELD	UNTREATED	TREATED
47	230	670
51	330	800
60	280	990
80	300	590
AVERAGE:	280	760

BOARD PROPERTIES AND PERFORMANCE

SLIDE MATERIAL

FOR

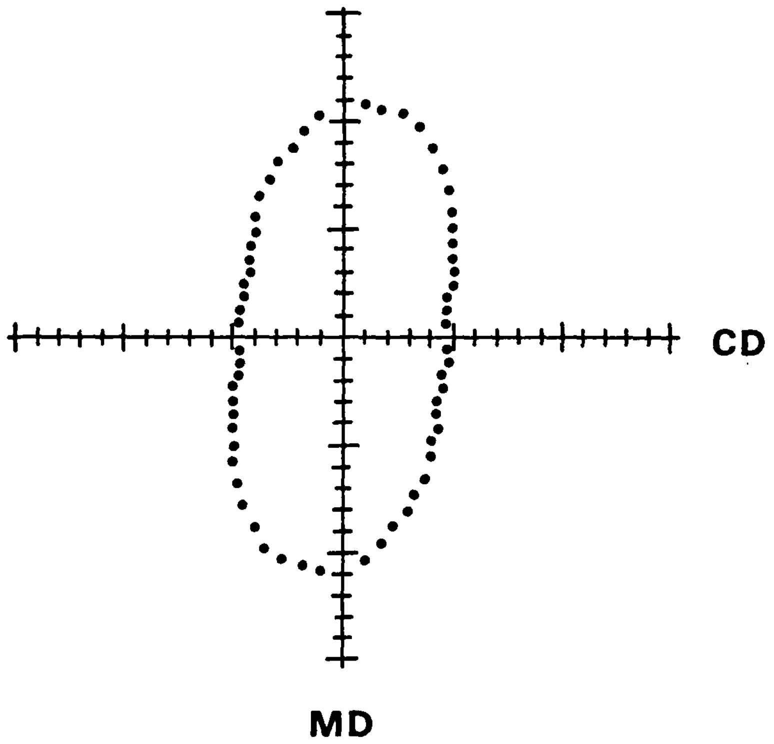
PROJECT 3571

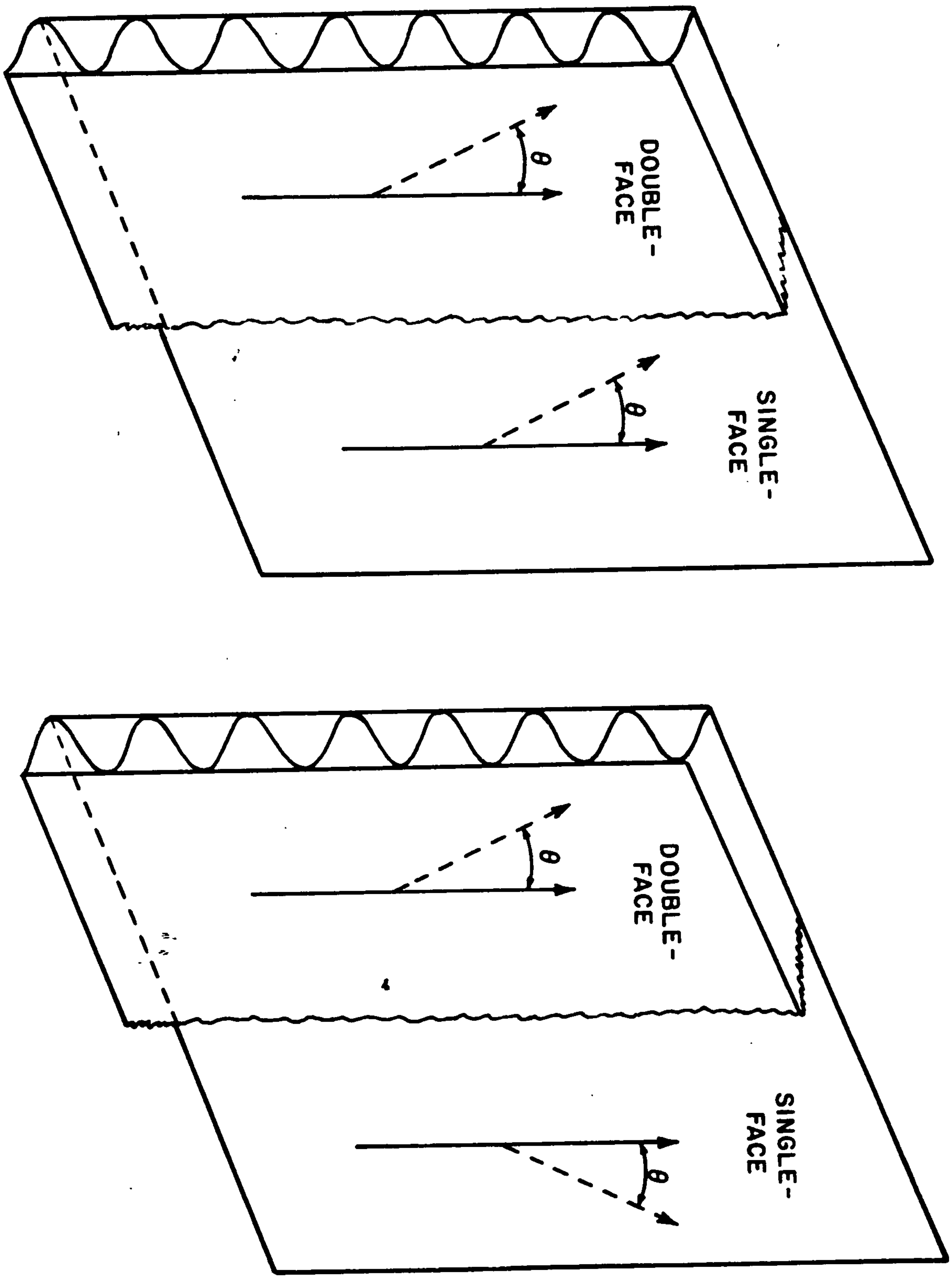
TO THE

PAPER PROPERTIES AND USES

PROJECT ADVISORY COMMITTEE

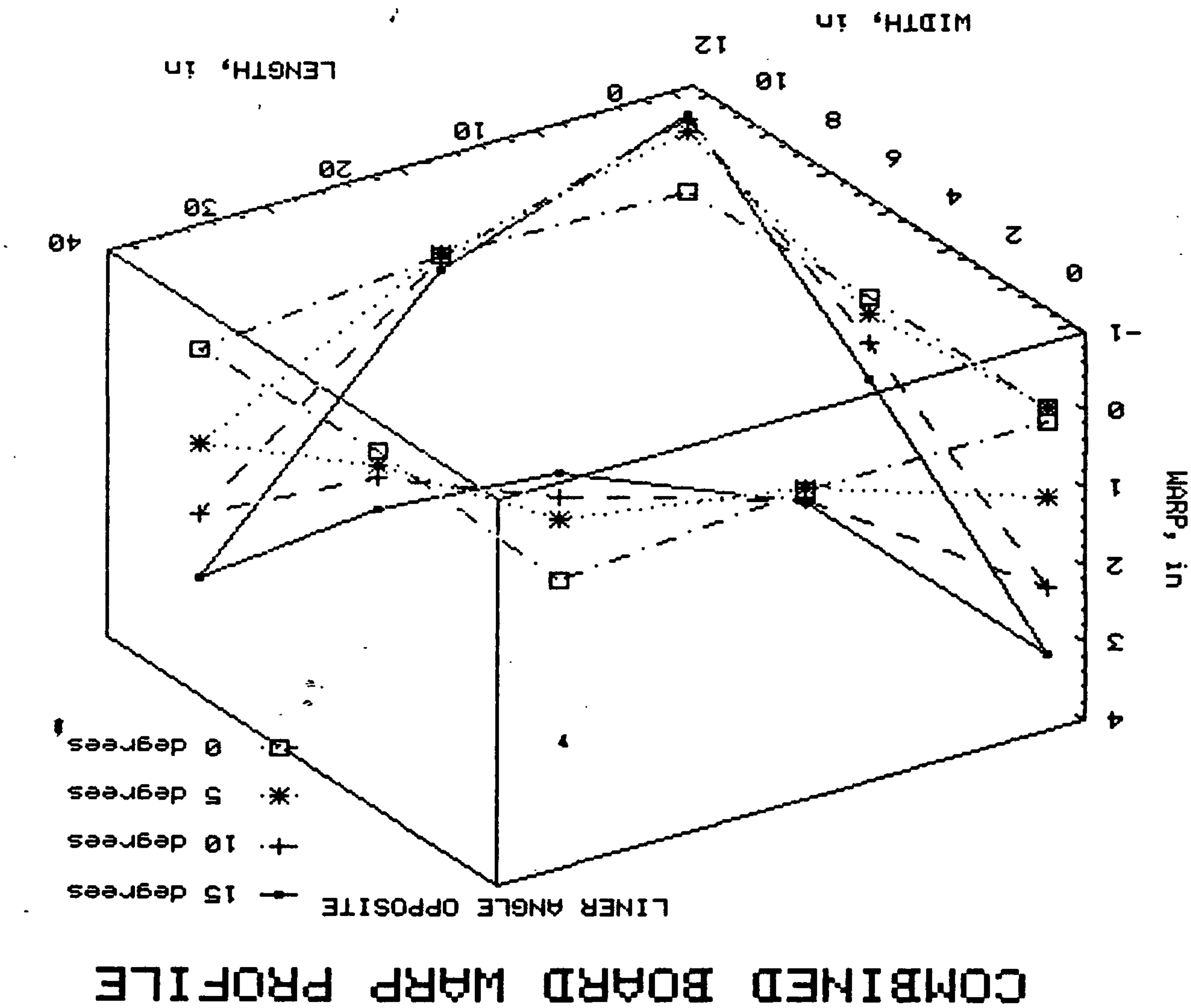
March 21, 1990

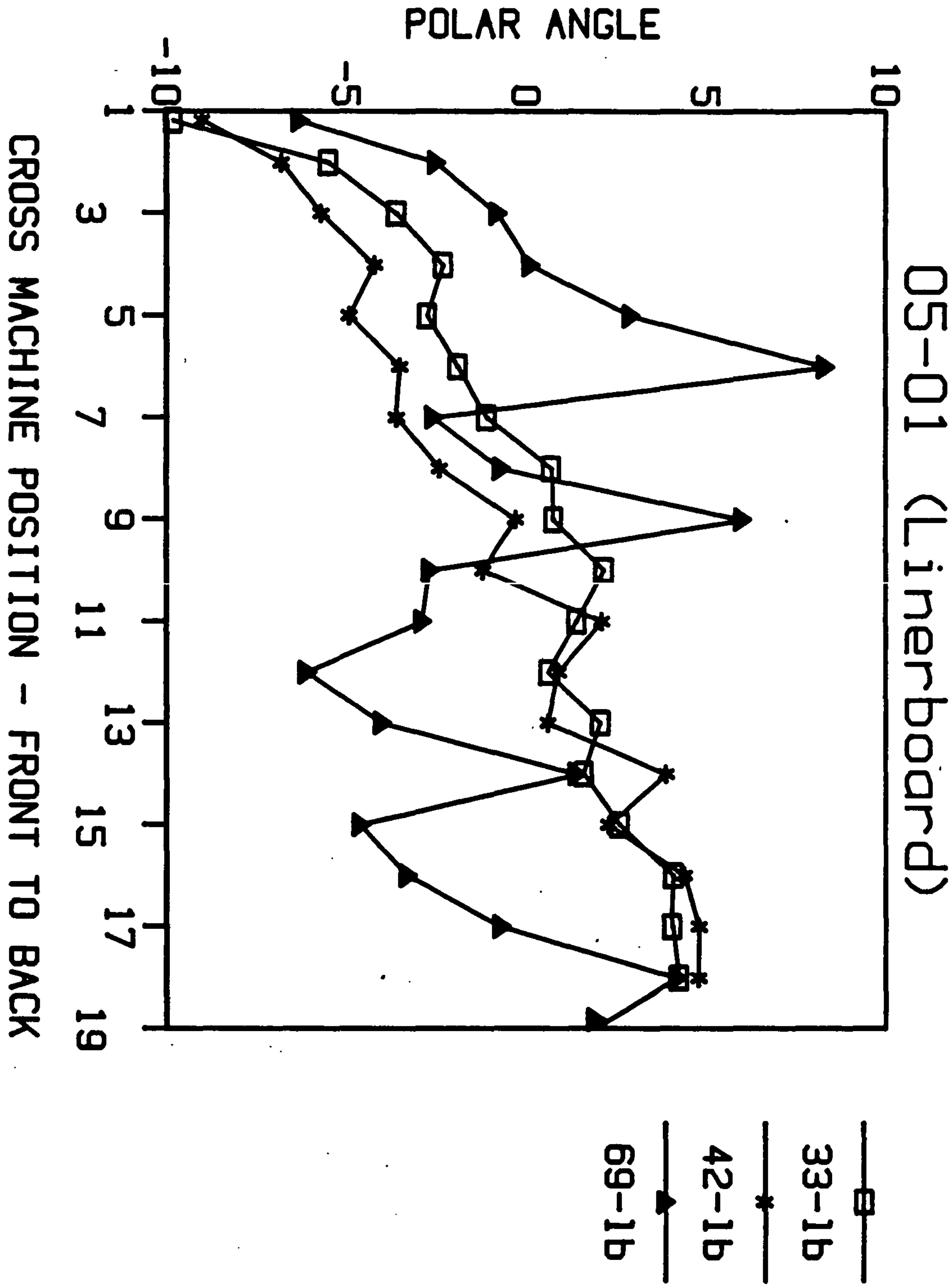

CD
MD

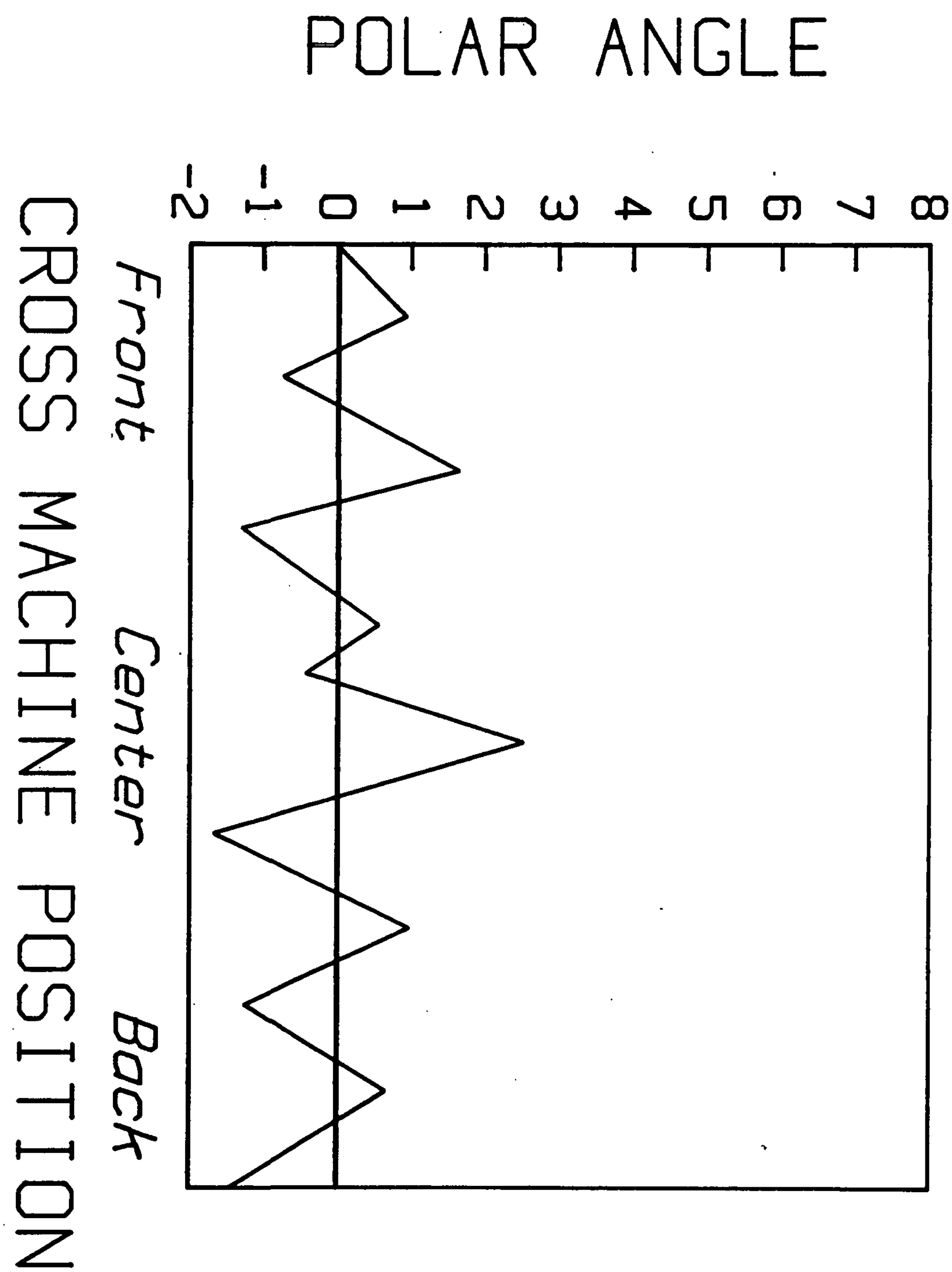


a) Liner polar angles in same direction

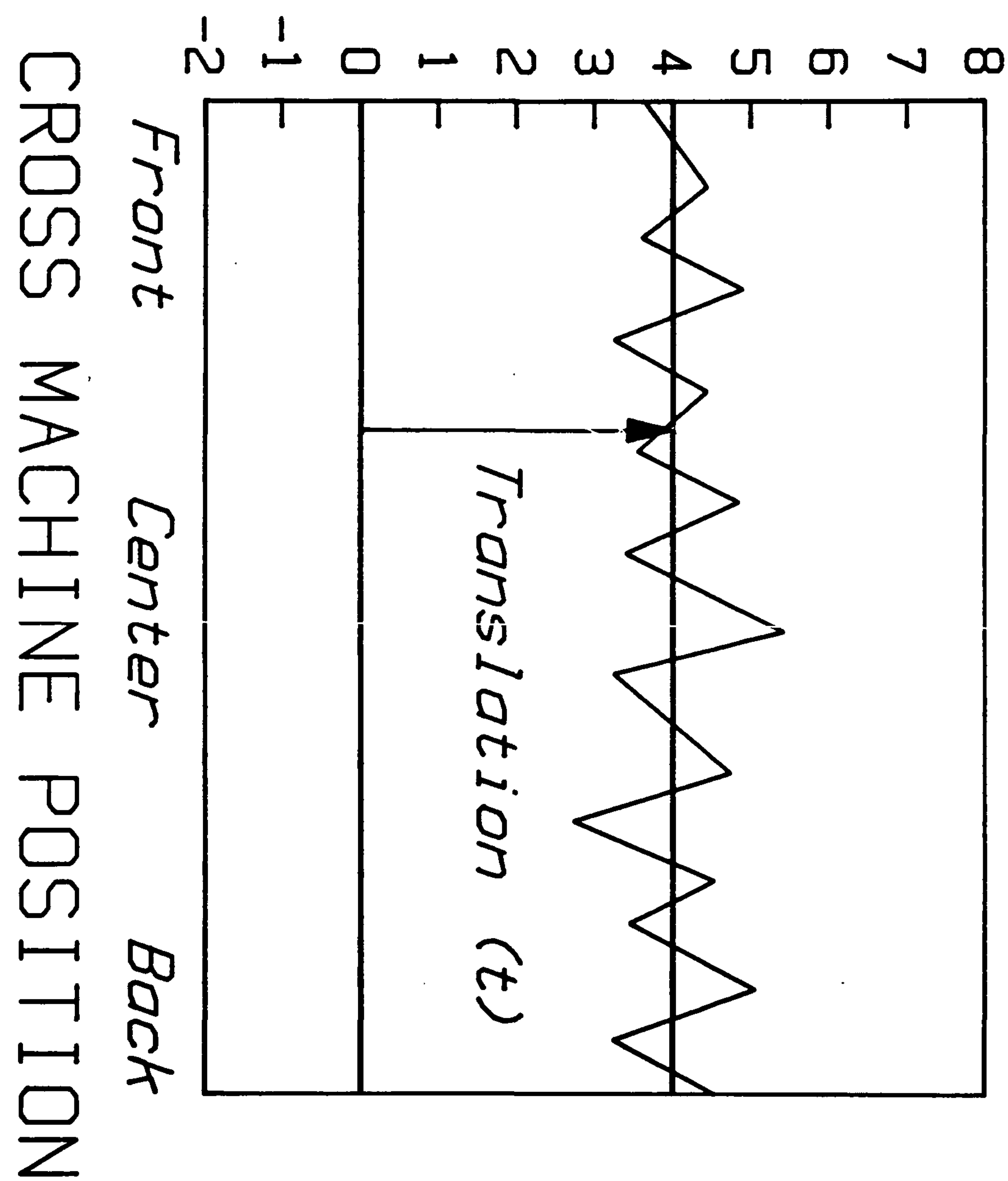
b) Liner polar angles in opposite direction

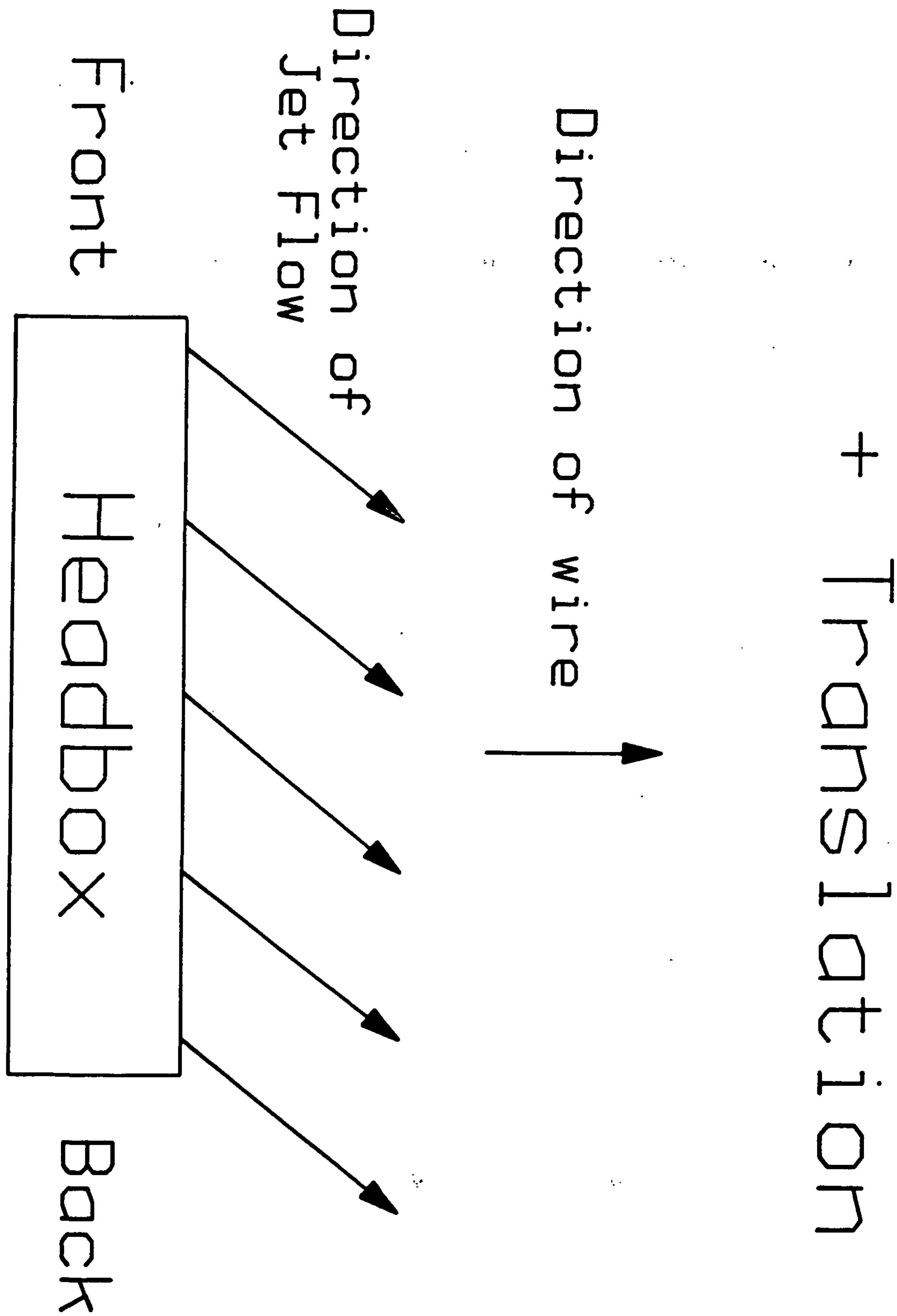

COMBINED BOARD WARP PROFILE
LINER ANGLE OPPOSITE
0 degrees
5 degrees
10 degrees
15 degrees
LENGTH, in
WIDTH, in
WARP, in
0
10
20
30
40
0
2
4
6
8
10
12
-1
0
1
2
3
4

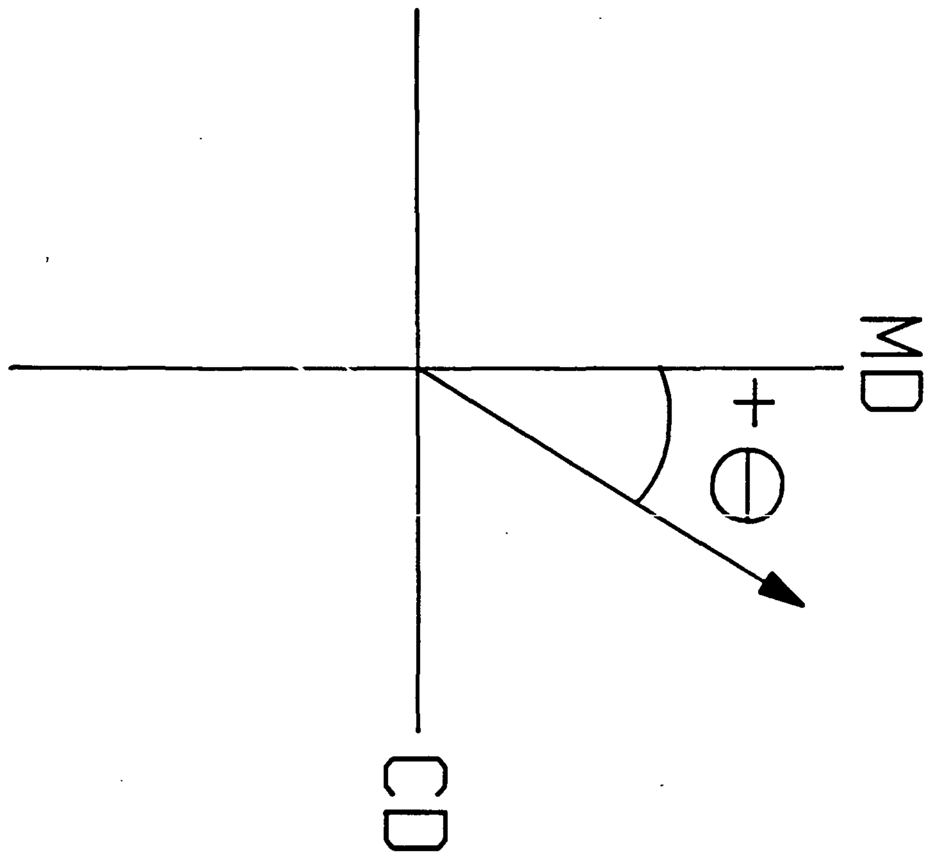

05-01 (Linerboard)
POLAR ANGLE
10
5
0
-5
-10
1
3
5
7
9
11
13
15
17
19
CROSS MACHINE POSITION - FRONT TO BACK
33-lb
42-lb
69-lb

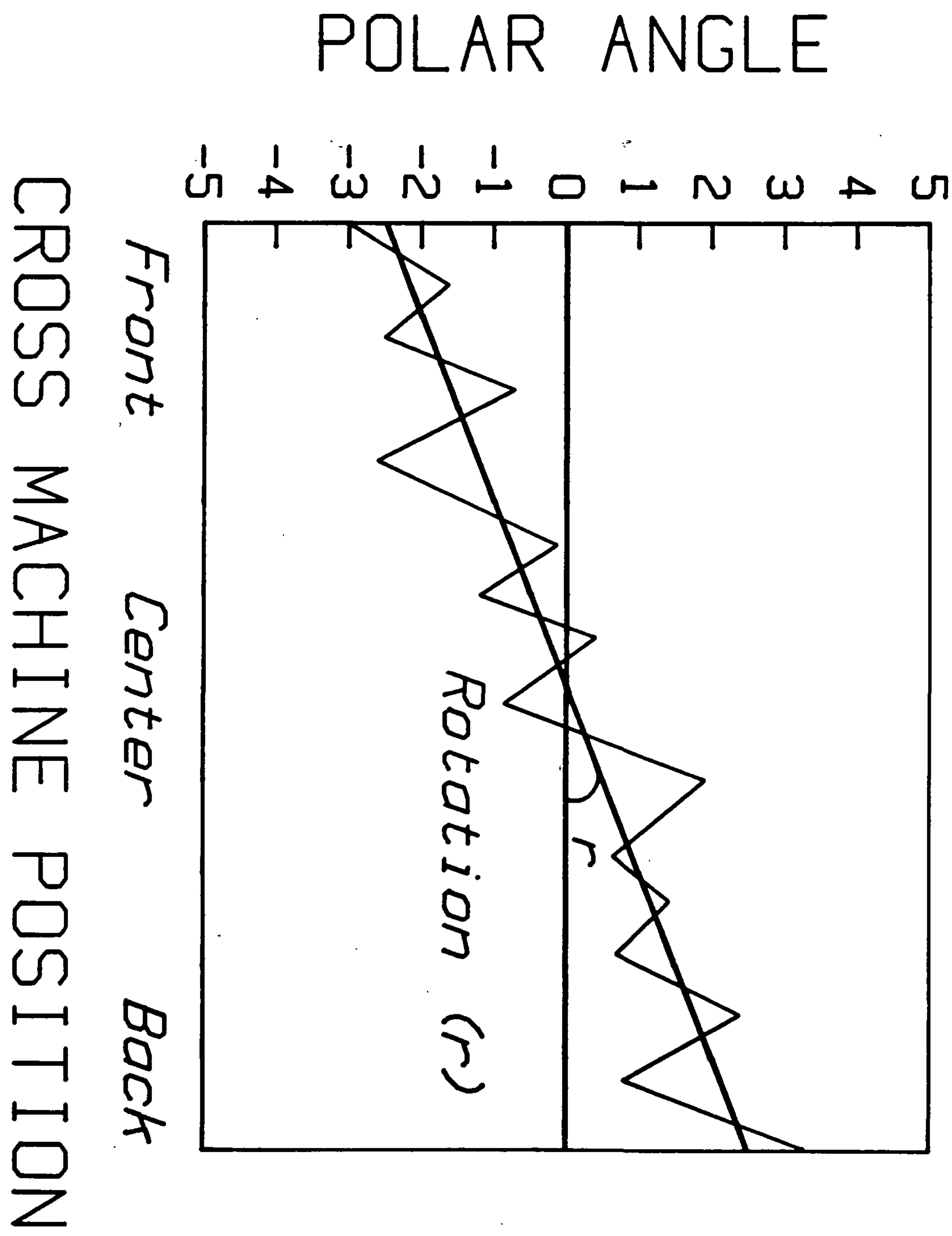

POLAR ANGLE
-2
-1
0
1
2
3
4
5
6
7
8
Front
Center
Back
CROSS MACHINE POSITION

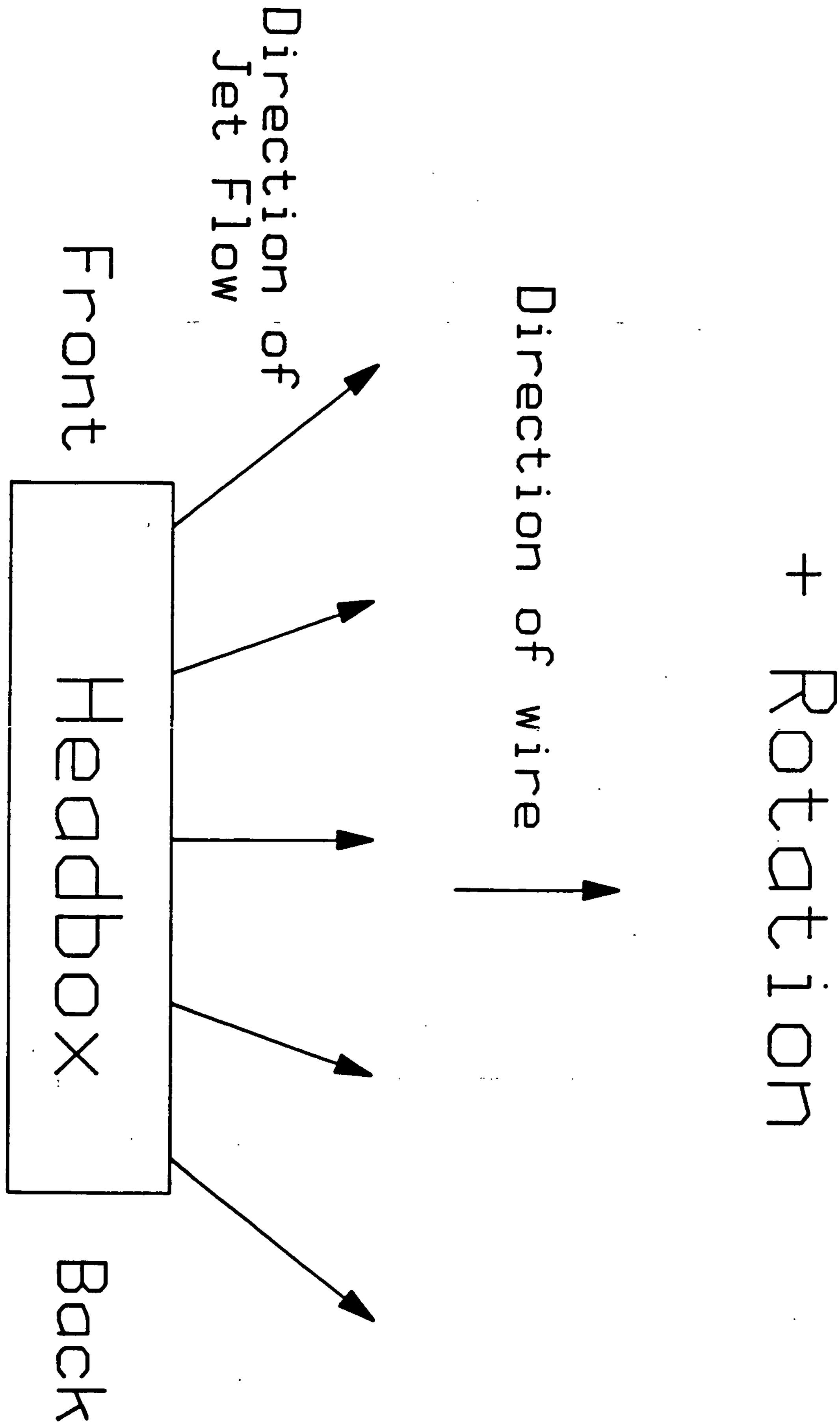
POLAR ANGLE

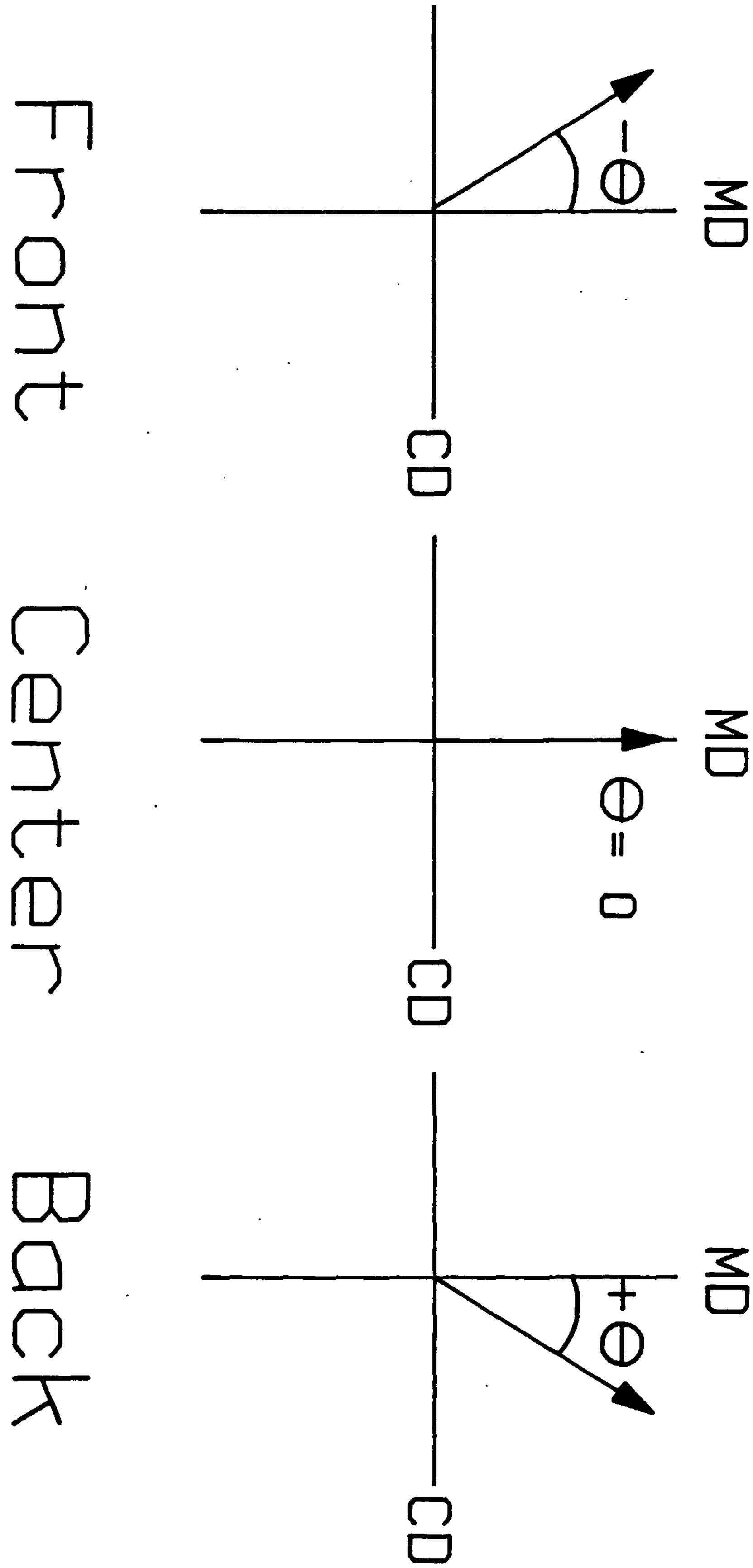

-2
-1
0
1
2
3
4
5
6
7
8
Front
Center
Back
Translation (t)
CROSS MACHINE POSITION


+ Translation
Direction of wire
Direction of Jet Flow
Front
Headbox
Back


MD
CD
+θ


POLAR ANGLE
-5 -4 -3 -2 -1 0 1 2 3 4 5
Front
Center
Back
Rotation (r)
r
CROSS MACHINE POSITION


Direction of
Jet Flow
Front
Direction of wire
+ Rotation
Headbox
Back


MD
CD
$-\theta$
Front
MD
CD
$\theta = 0$
Center
MD
CD
$+\theta$
Back

COMPONENTS OF POLAR ANGLE VS. POSITION CURVE

1. TRANSLATION, t

2. ROTATION, r

3. VARIATION, σ

EQUATIONS

$$Y = MX + B$$

POLAR ANGLE = M (CROSS REEL POSITION) + B

TRANSLATION = M (CENTER POSITION) + B

ROTATION = ARCTAN (M)

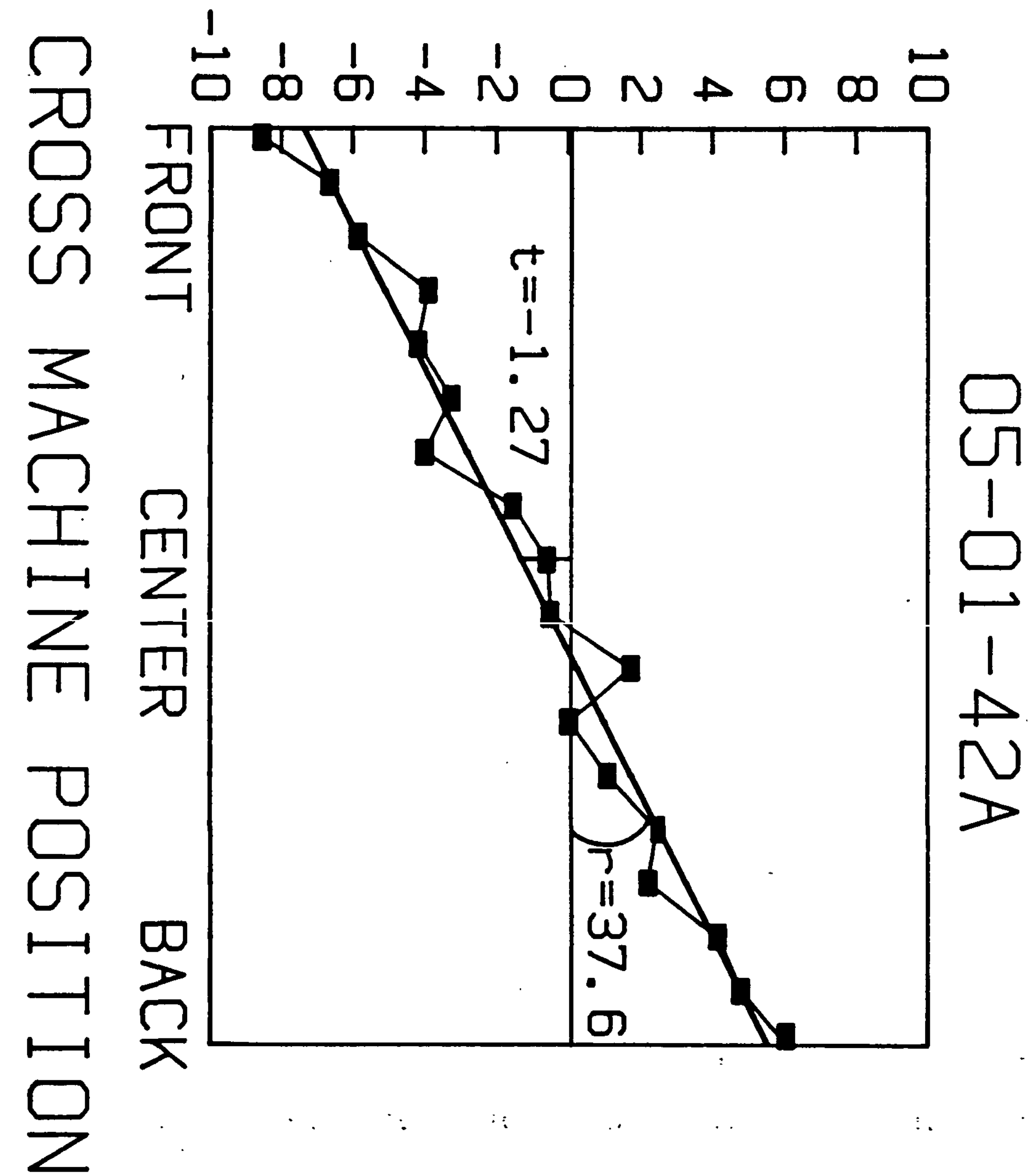
VARIATION = STANDARD DEVIATION

SUMMARY OF RESULTS

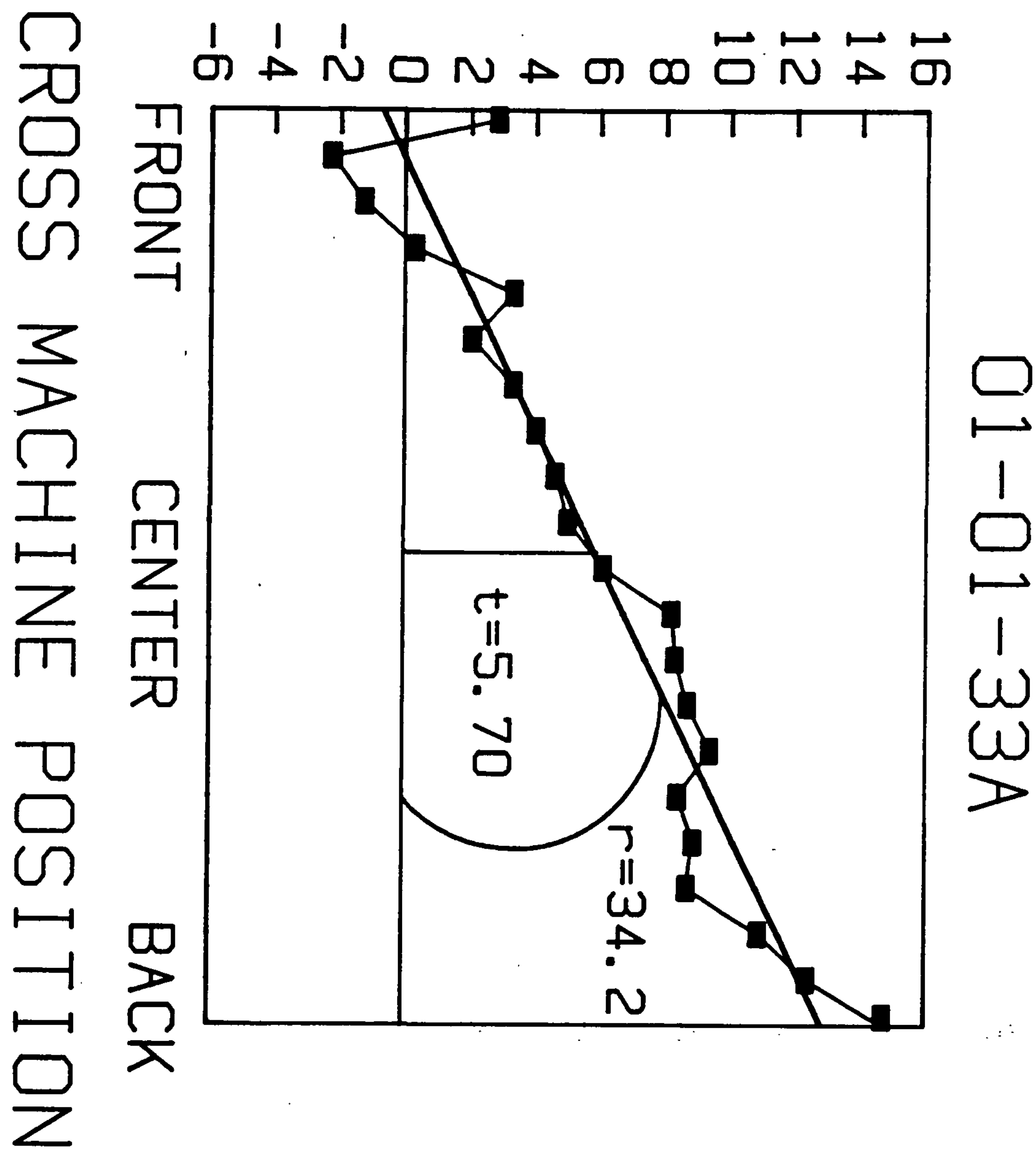
		RANGE	NO. OF MACHINES
TRANSLATION			
	+	0 to +8.2	1 (>5)
	−	0 to −5.3	1 (>5)
ROTATION			
	+	0 to +37.6	7 (>20)
	−	0 to −30.1	2 (>20)
VARIATION			
		0.72 to 2.00	

SAMPLE	TRANSLATION t	ROTATION r	VARIATION sigma
01-01-26A	8.19	33.4	1.21
01-01-33A	5.70	34.2	1.20
05-01-33A	-0.52	33.4	1.30
05-01-42A	-1.27	37.6	0.90
05-01-69A	N.S.	N.S.	2.00
06-01-42A	-5.31	17.2	1.41
06-01-69A	-4.82	20.8	1.49
16-01-26A	1.09	25.6	0.97
16-01-33A	1.89	N.S.	0.99

POLAR ANGLE


05-01-42A
t=-1.27
r=37.6
10
8
6
4
2
0
-2
-4
-6
-8
-10
FRONT
CENTER
BACK
CROSS MACHINE POSITION

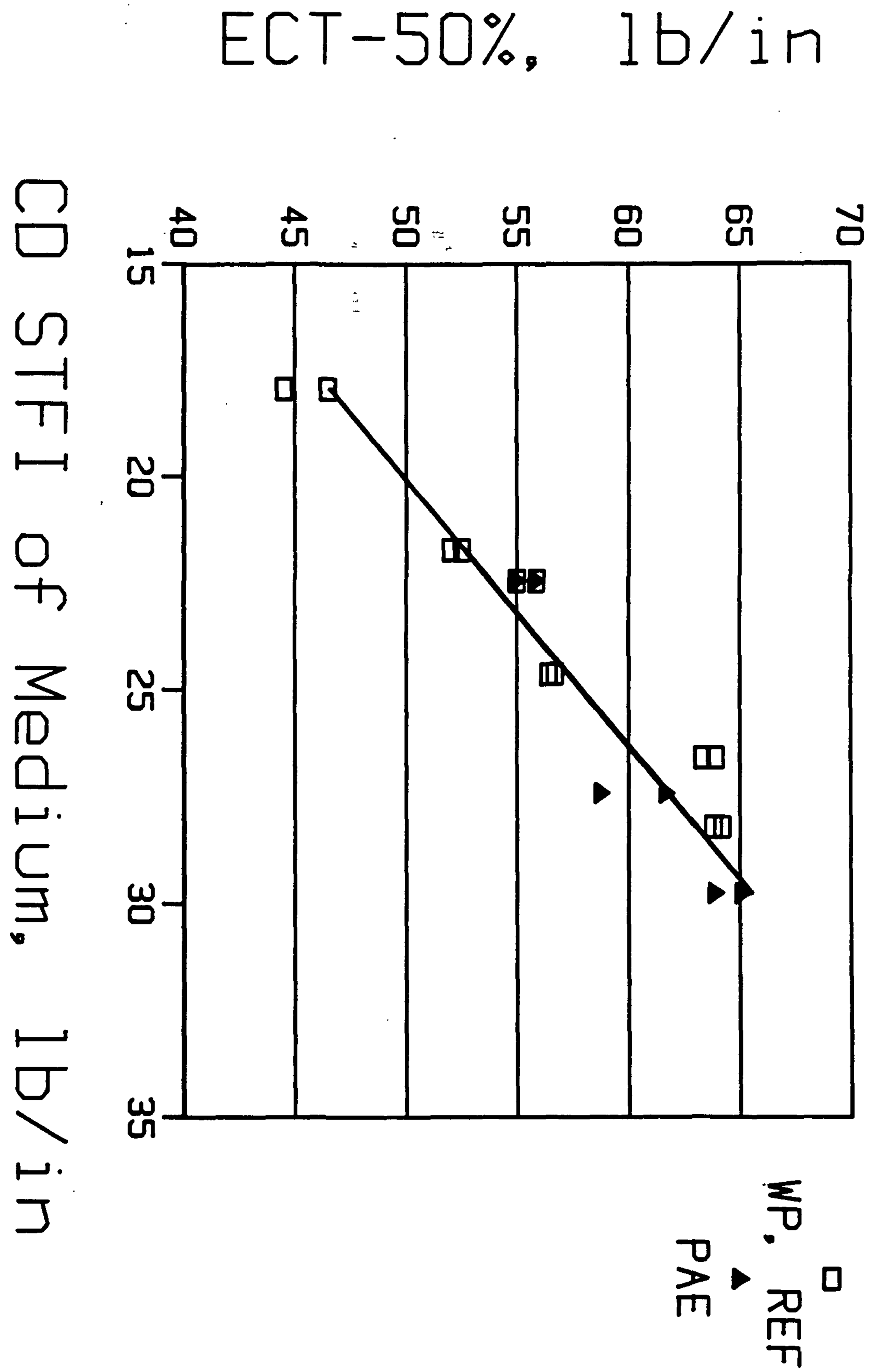
POLAR ANGLE

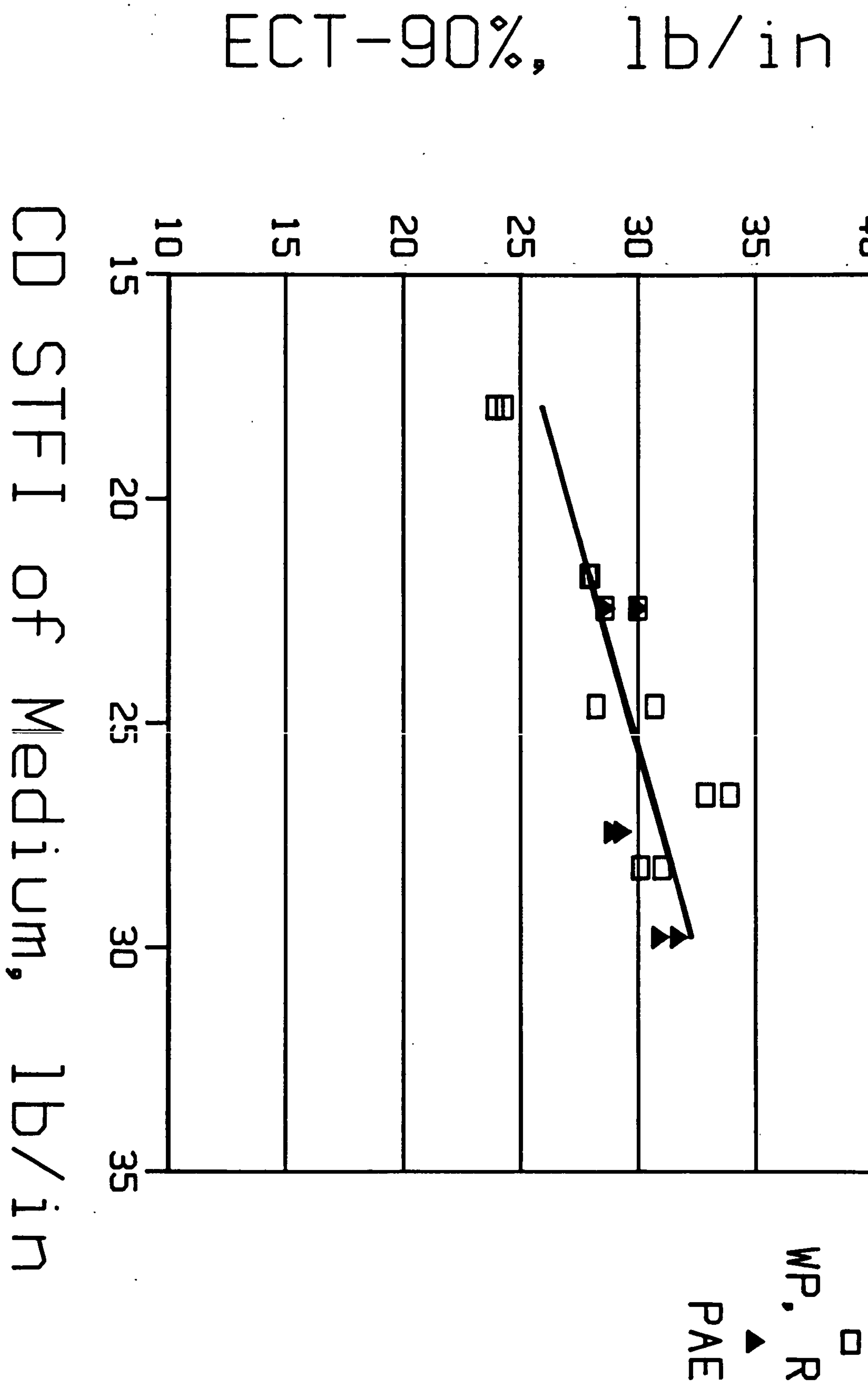

01-01-33A
16
14
12
10
8
6
4
2
0
-2
-4
-6
t=5.70
r=34.2
FRONT
CENTER
BACK
CROSS MACHINE POSITION

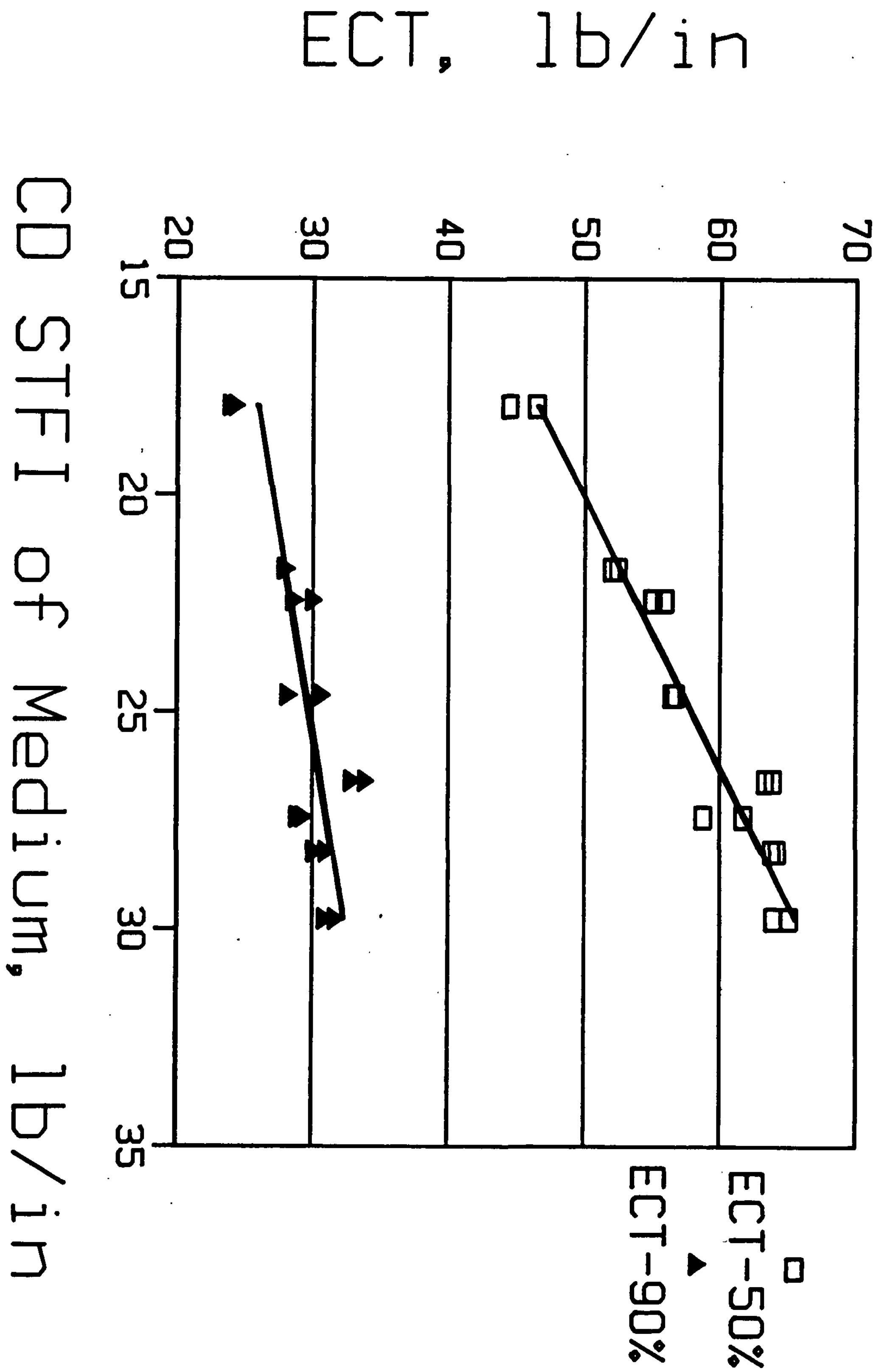
Variables Studied

Variable	Level		
Freeness (CSF)	250	325	400
Wet Pressing	L, M	L, M	L,M
Strength Additive (%)[1]		0.5, 1%	
Speed (fpm)	200, 400	200,400	200,400

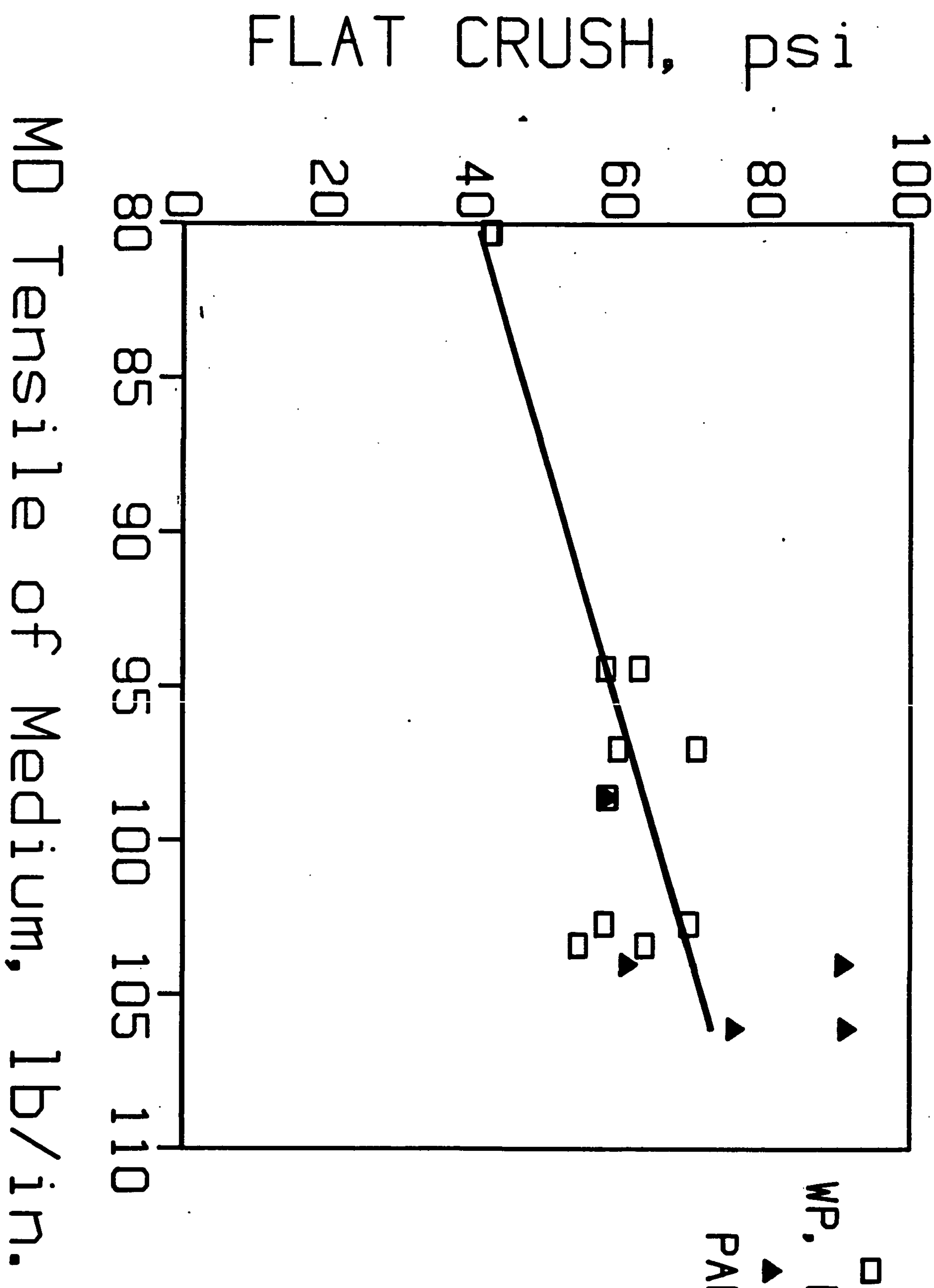
[1] Additive used at the medium wet pressing level.


ECT-50%, lb/in
40
45
50
55
60
65
70
15
20
25
30
35
CD STFI of Medium, lb/in
WP, REF
PAE


ECT-90%, lb/in
10
15
20
25
30
35
40
15
20
25
30
35
CD STFI of Medium, lb/in
WP, REF
PAE



ECT, lb/in
20
30
40
50
60
70
15
20
25
30
35
CD STFI of Medium, lb/in
ECT-50%
ECT-90%


FLAT CRUSH, psi
0
20
40
60
80
100
80
85
90
95
100
105
110
MD Tensile of Medium, lb/in.
WP, REF
PAE

FUNDAMENTALS OF PAPER SURFACE WETTABILITY

SLIDE MATERIAL

FOR

PROJECT 3646

TO THE

PAPER PROPERTIES AND USES

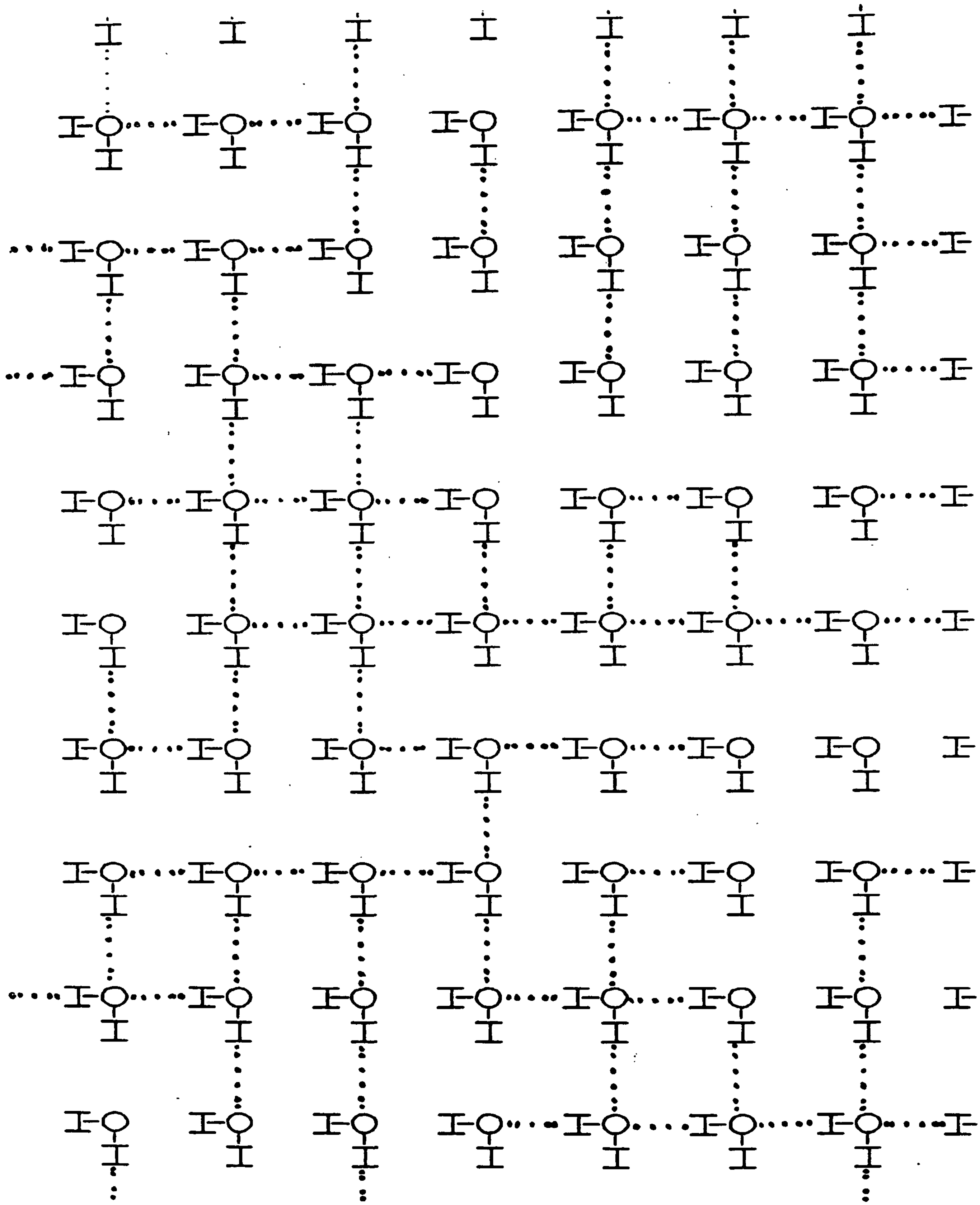
PROJECT ADVISORY COMMITTEE

March 21, 1990

Heat Capacities of Water near a Variety of Surfaces at 25°C

Substance	Heat capacity (cal/g°K)
Bulk water	1.00 ± 0.08
Porous glass	1.27 ± 0.20
Activated carbon	1.28 ± 0.03
Zeolite	1.21 ± 0.03
Diamond	1.20 ± 0.08
Collagen[a]	1.24
Egg albumin[a]	1.25 ± 0.02
DNA[a]	1.26 ± 0.06
Artemia cysts[a]	1.28 ± 0.07

[a] See references listed in (10).



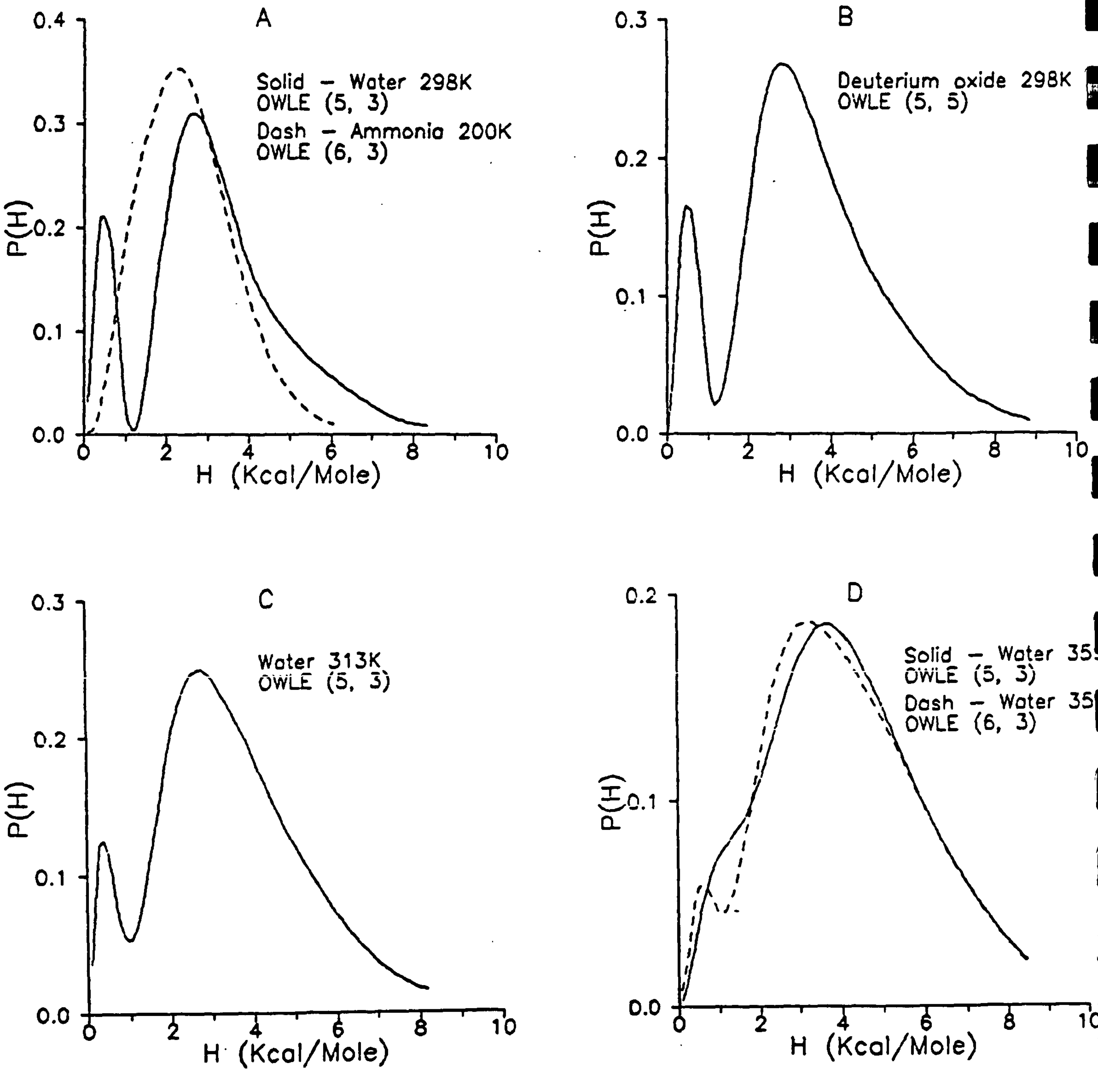

A
Solid – Water 298K
OWLE (5, 3)
Dash – Ammonia 200K
OWLE (6, 3)
P(H)
H (Kcal/Mole)
B
Deuterium oxide 298K
OWLE (5, 5)
P(H)
H (Kcal/Mole)
C
Water 313K
OWLE (5, 3)
P(H)
H (Kcal/Mole)
D
Solid – Water 35
OWLE (5, 3)
Dash – Water 35
OWLE (6, 3)
P(H)
H (Kcal/Mole)

Fig #1

$$\alpha_p = \sigma^2_{ev} / VRT^2$$

$$C_p = \sigma^2_h / RT^2$$

$$\beta_T = \sigma^2_v / VRT$$

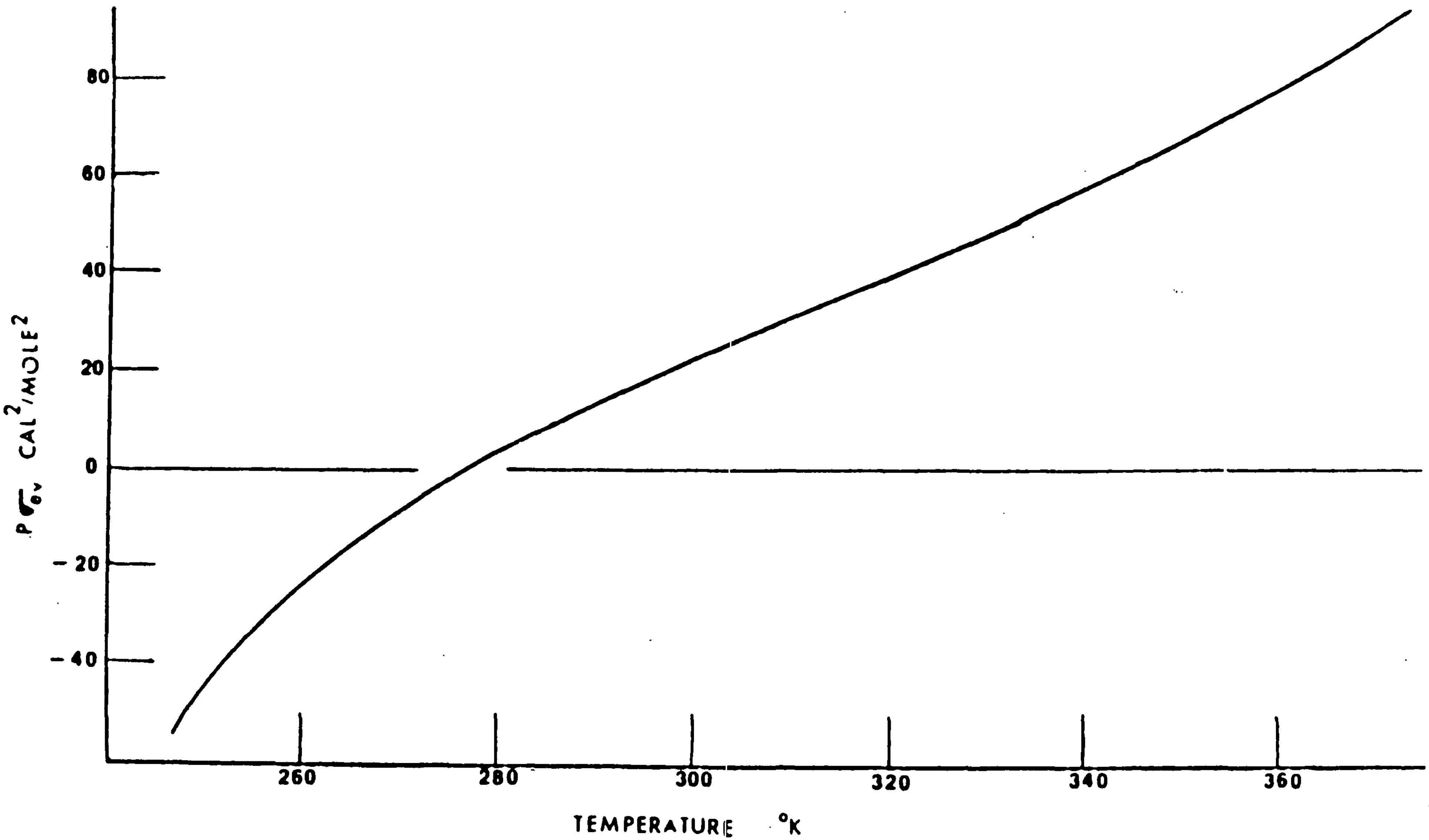
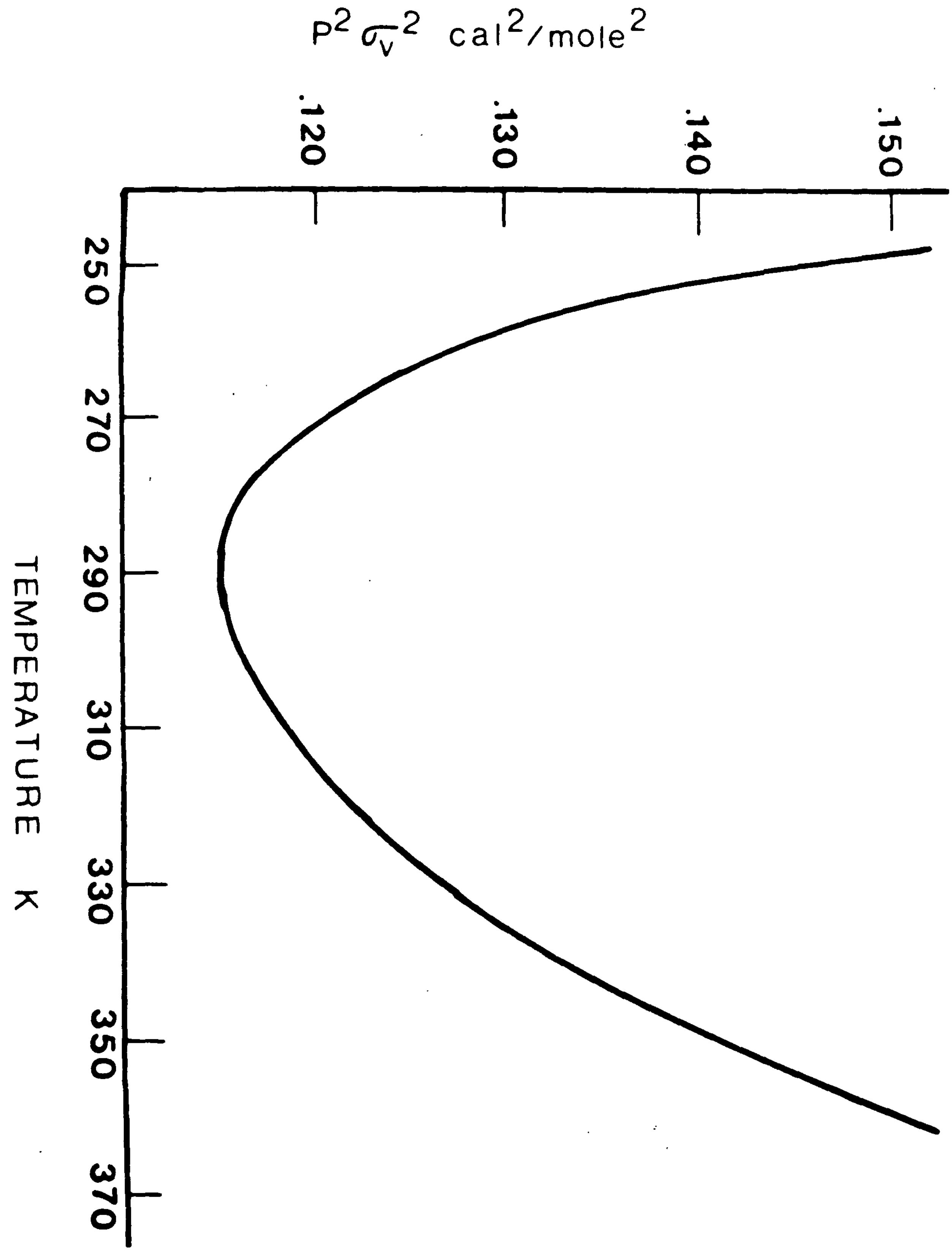
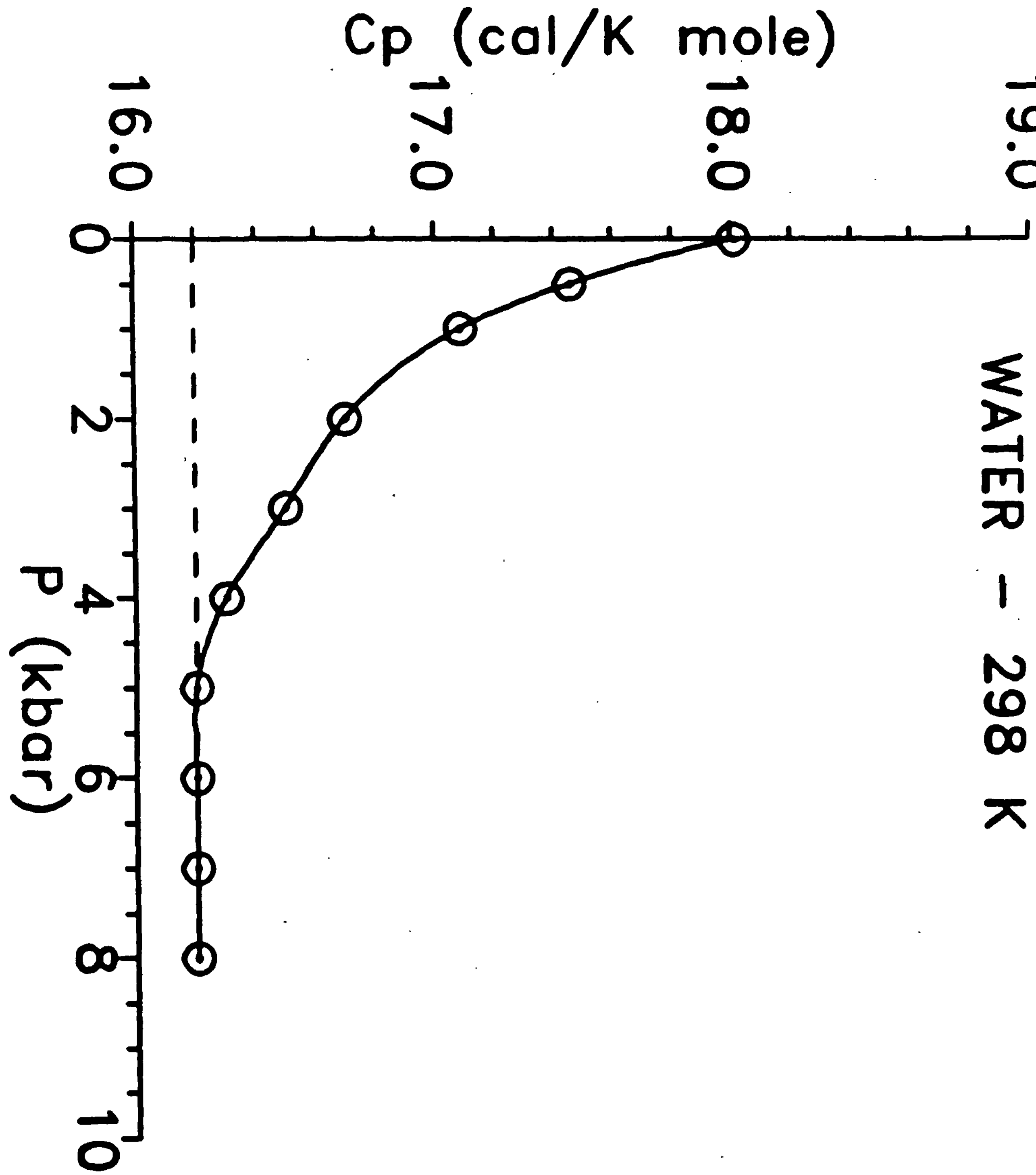


FIG. 8. Covariance between volume and energy for water as a function of temperature, calculated from thermal expansivities by Kell (33). Note negative values below 4°C, suggesting low-energy high-volume states.


$P^2 \sigma_v^2$ cal^2/mole^2
.120
.130
.140
.150
250
270
290
310
330
350
370
TEMPERATURE K

$$Cp = X_1 Cp_1 + X_2 Cp_2 + X_1 X_2 \left[\frac{\Delta H^2}{R T^2} \right]$$

$$\Delta H = H_2 - H_1$$


WATER - 298 K
Cp (cal/K mole)
19.0
18.0
17.0
16.0
P (kbar)
0
2
4
6
8
10

FRACTION OF 4-H BONDED MOLECULES AT 25°C

1.	Distribution Function	∿0.1
2.	Stanley and Texeria	0.14
3.	Partial Molar Heat Capacity	0.1

BOARD PROPERTIES AND PERFORMANCE

SLIDE MATERIAL

FOR

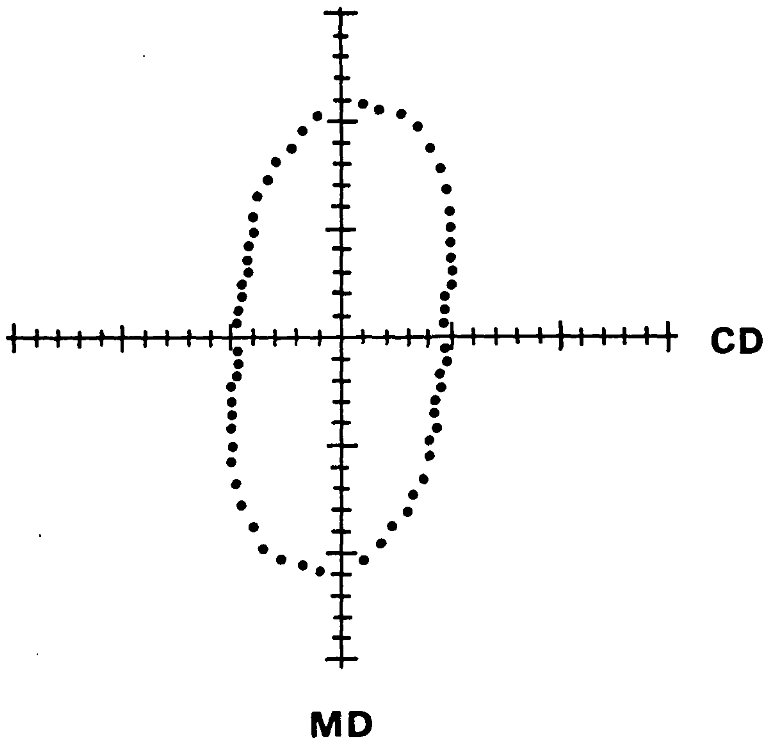
PROJECT 3571

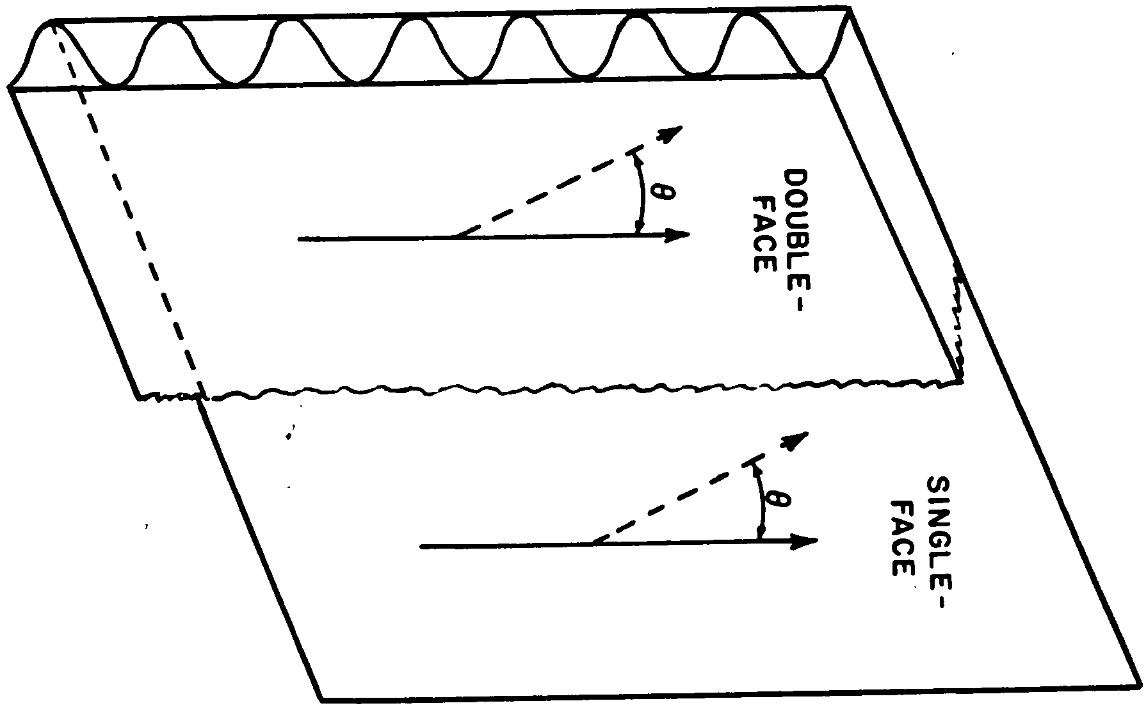
TO THE

PAPER PROPERTIES AND USES

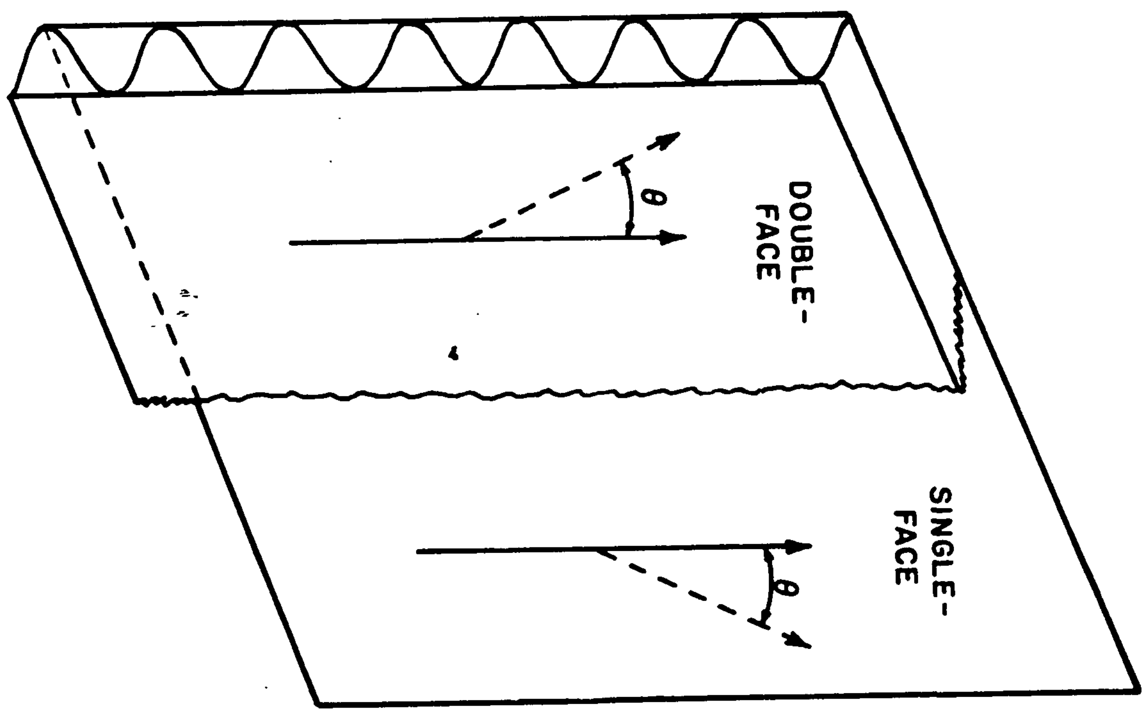
PROJECT ADVISORY COMMITTEE

March 21, 1990

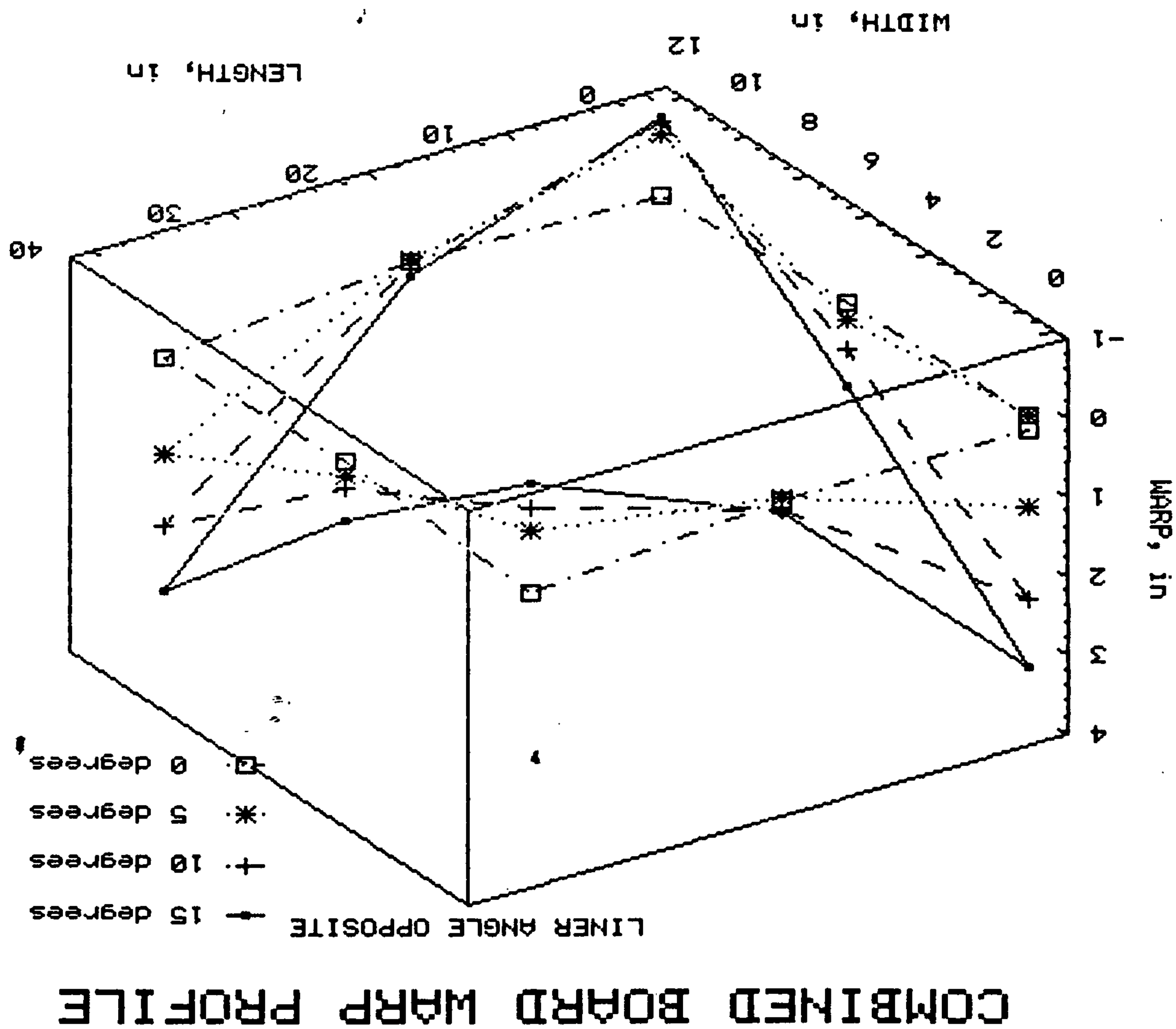

CD
MD

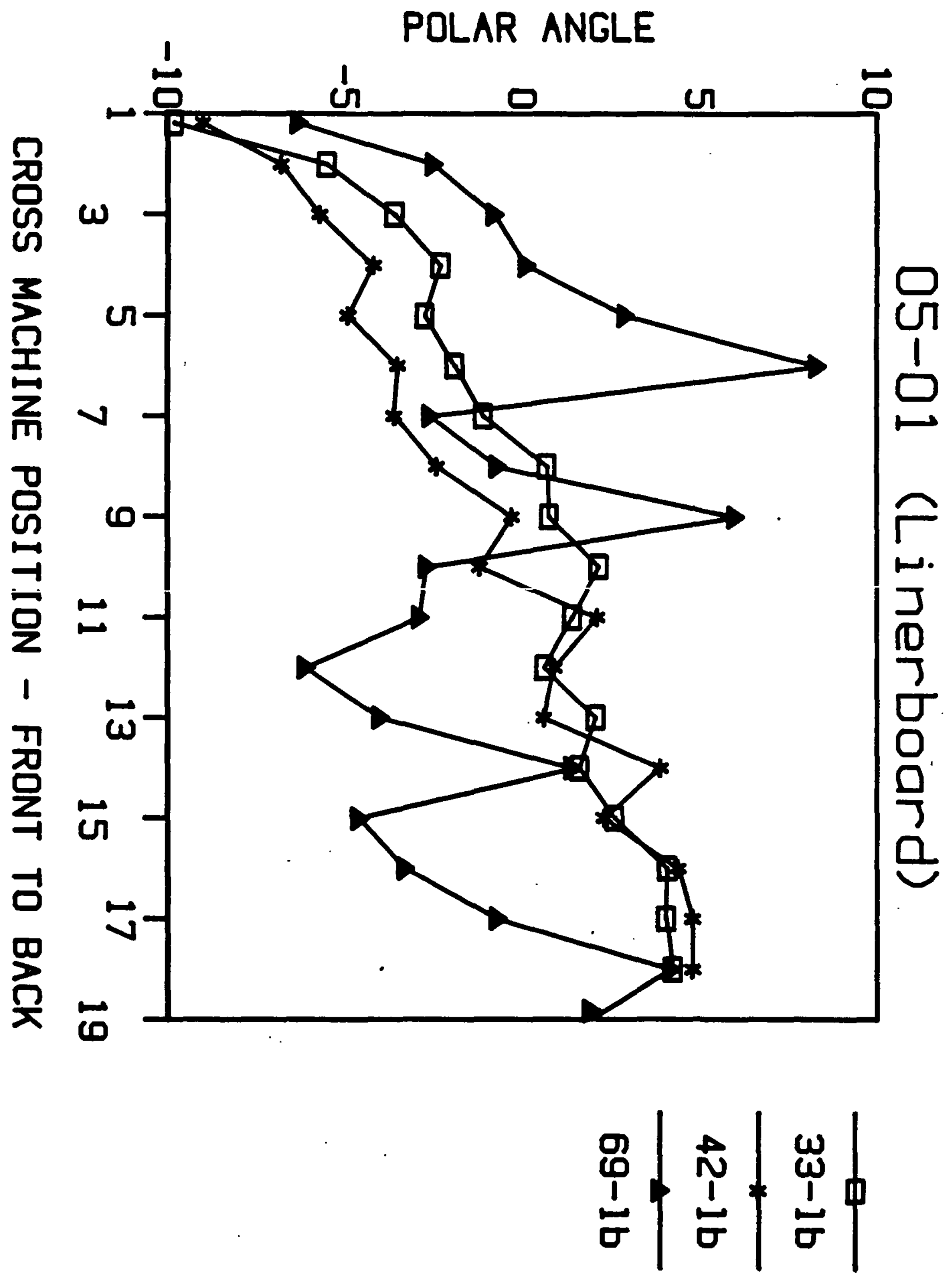


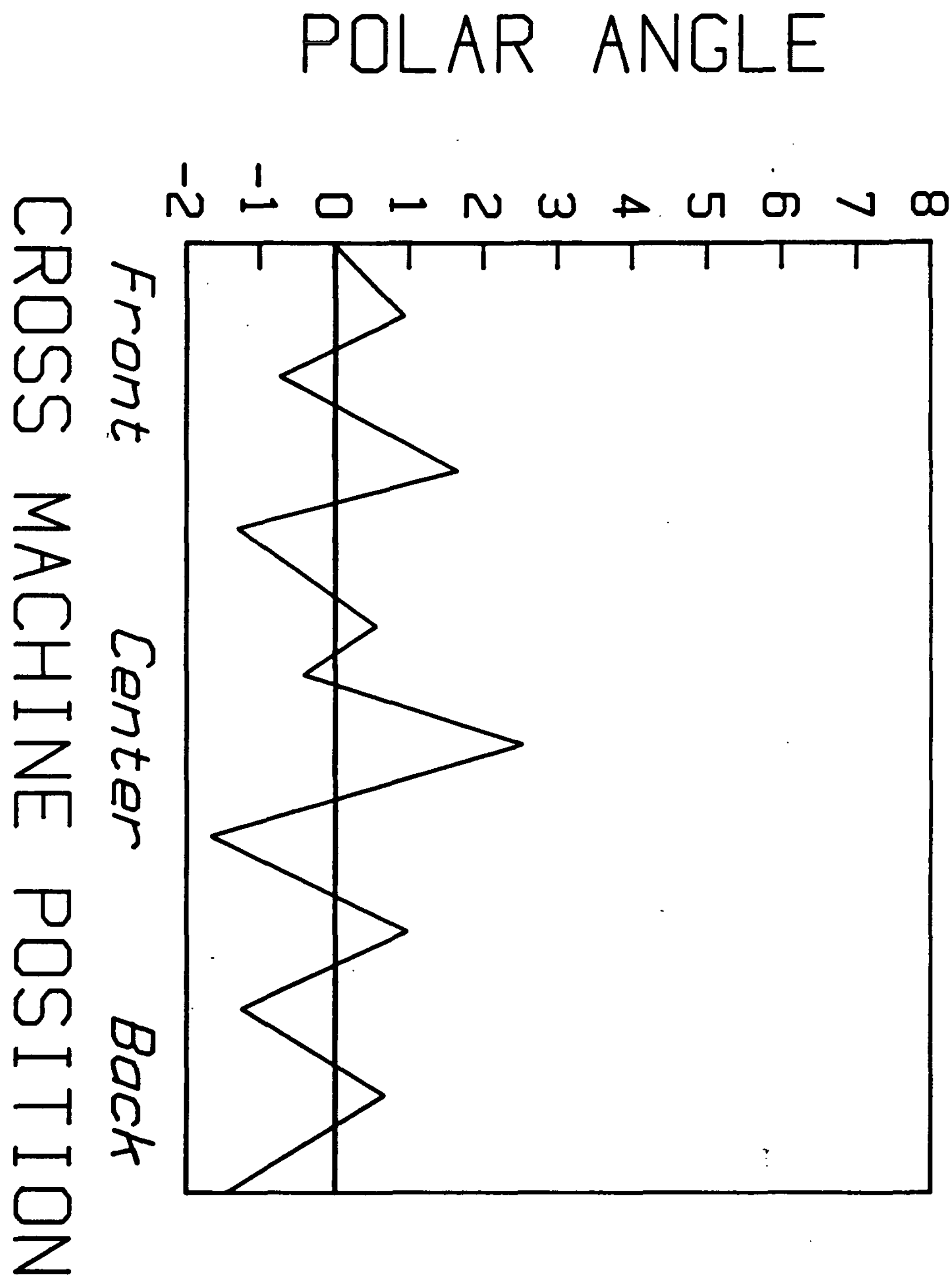
a) Liner polar angles in same direction

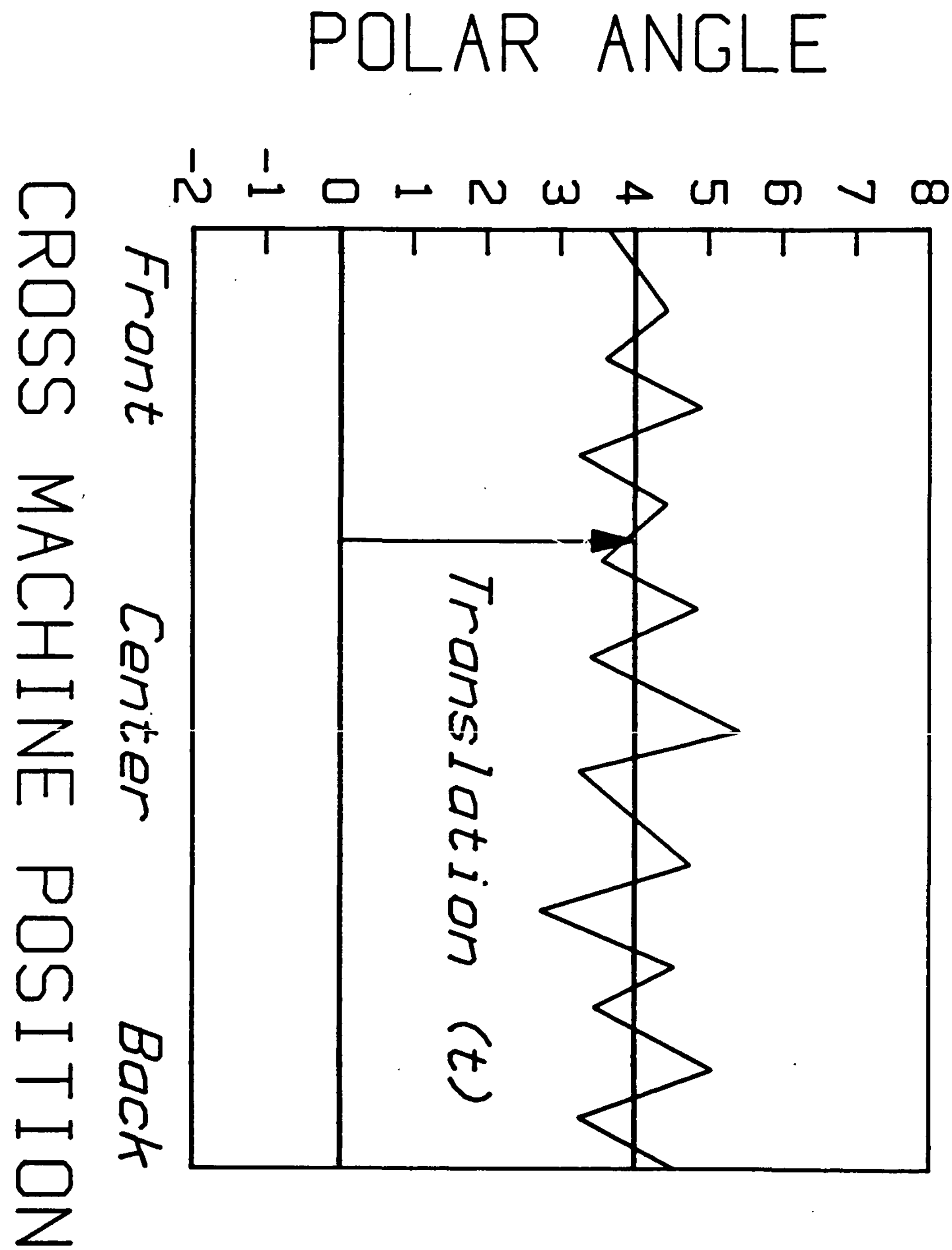


b) Liner polar angles in opposite direction

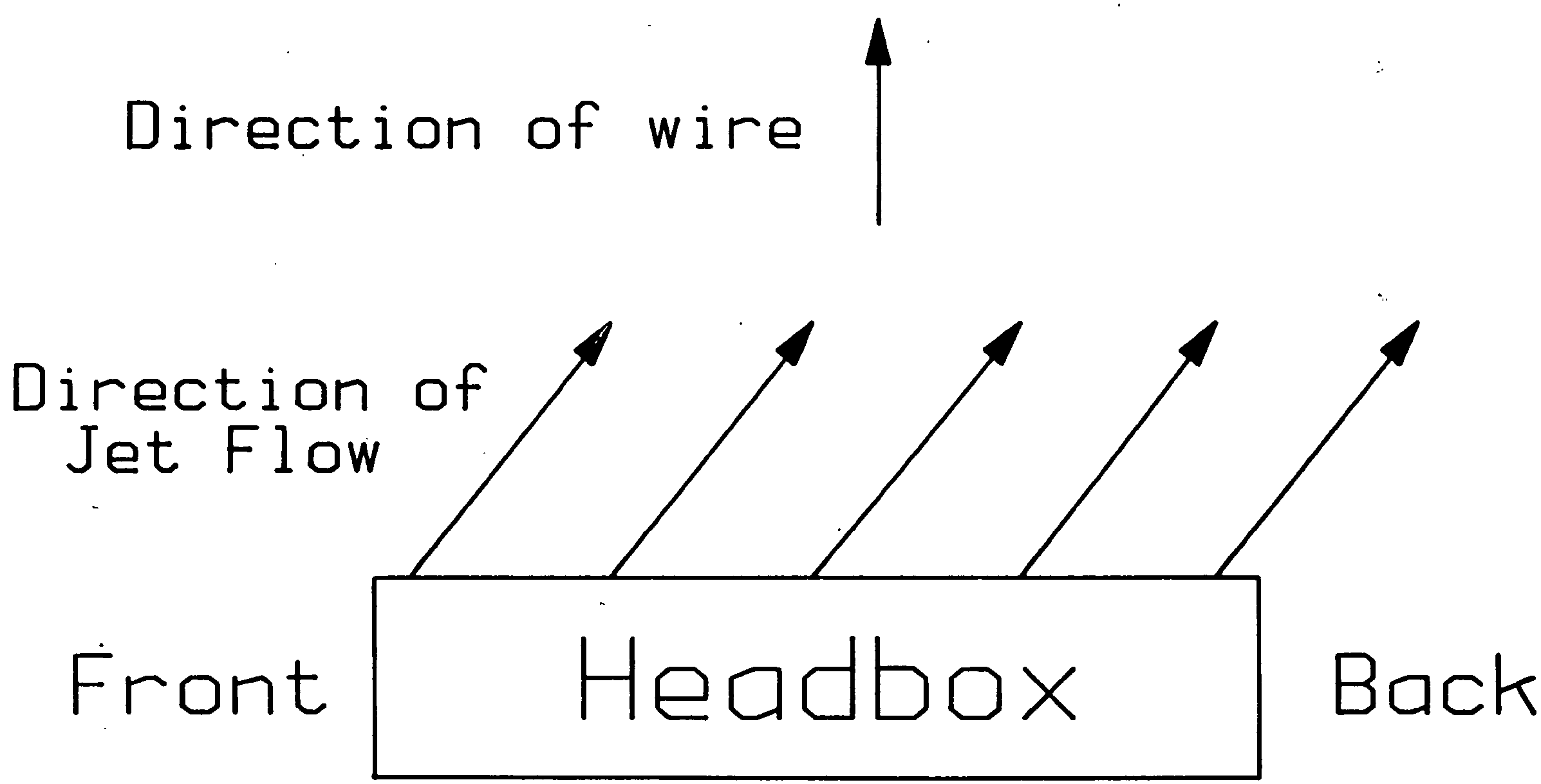

COMBINED BOARD WARP PROFILE
LINER ANGLE OPPOSITE
0 degrees
5 degrees
10 degrees
15 degrees
LENGTH, in
WIDTH, in
WARP, in

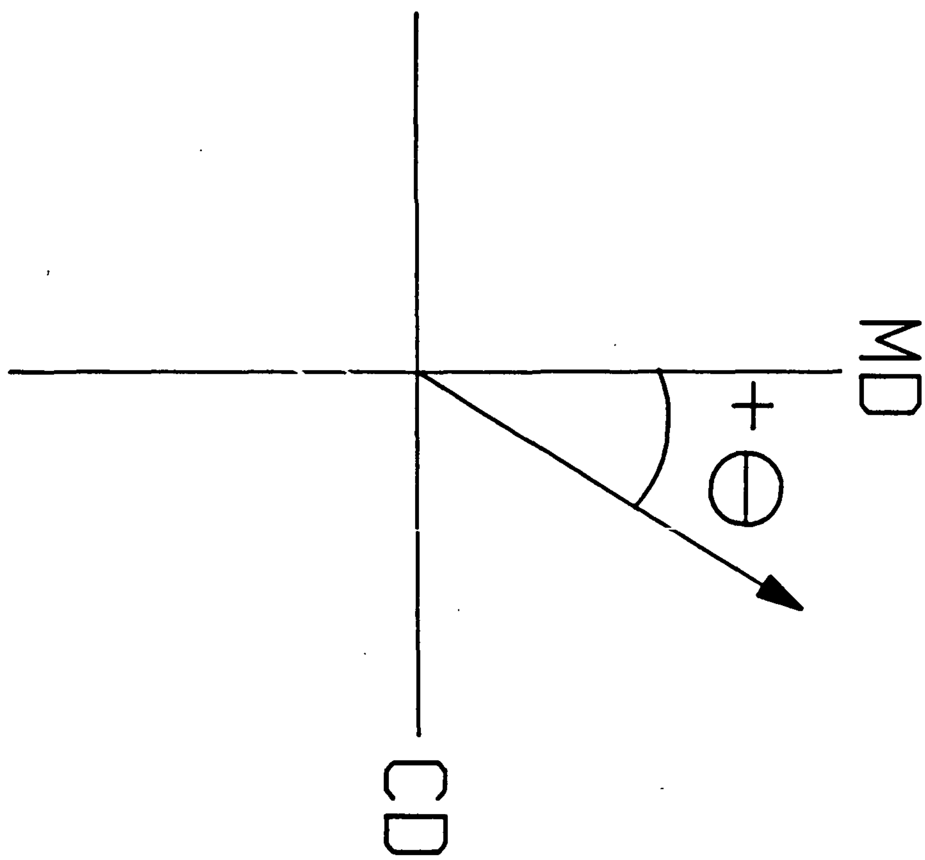

05-01 (Linerboard)
POLAR ANGLE
10
5
0
-5
-10
1
3
5
7
9
11
13
15
17
19
CROSS MACHINE POSITION - FRONT TO BACK
33-1b
42-1b
69-1b

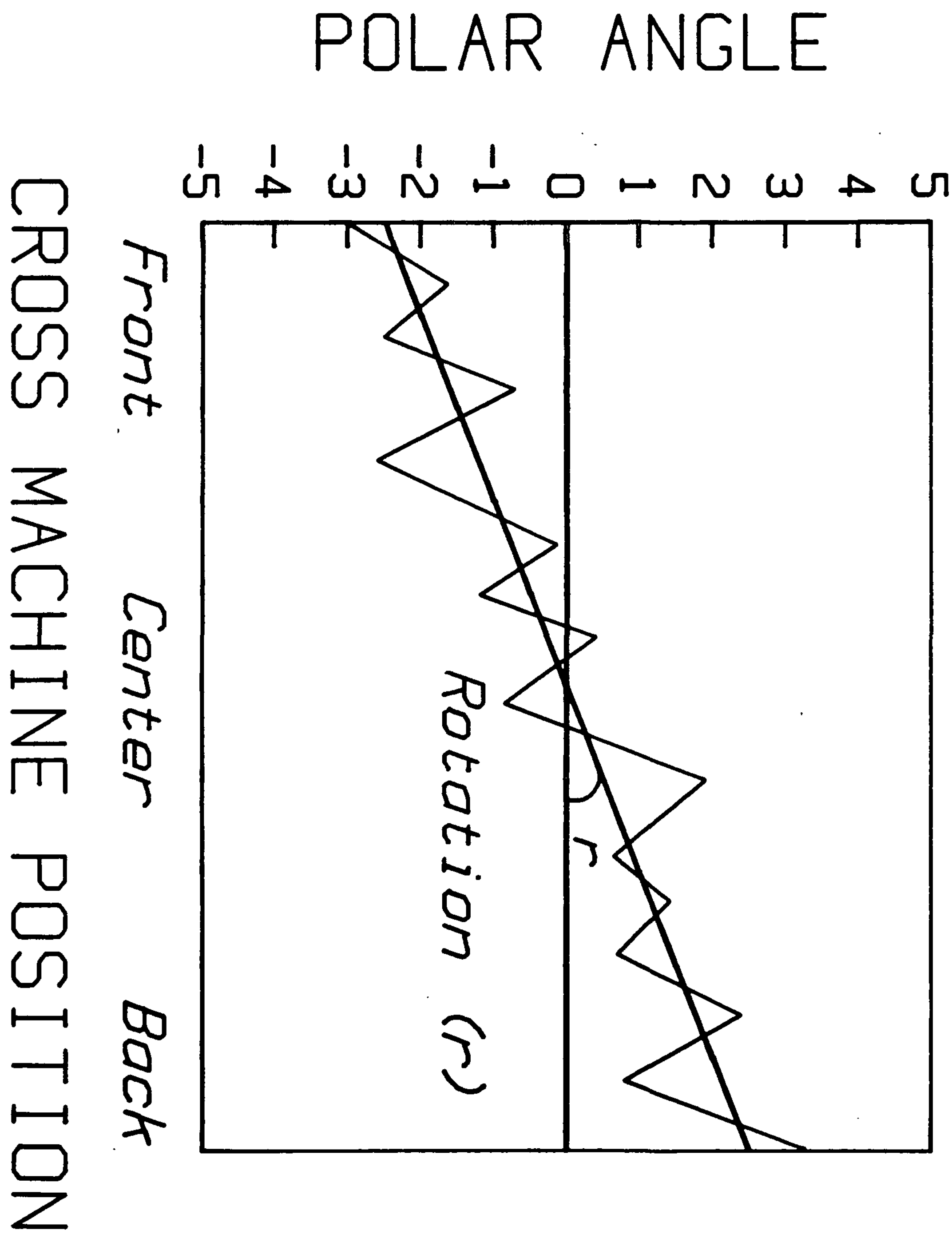

POLAR ANGLE
-2
-1
0
1
2
3
4
5
6
7
8
Front
Center
Back
CROSS MACHINE POSITION

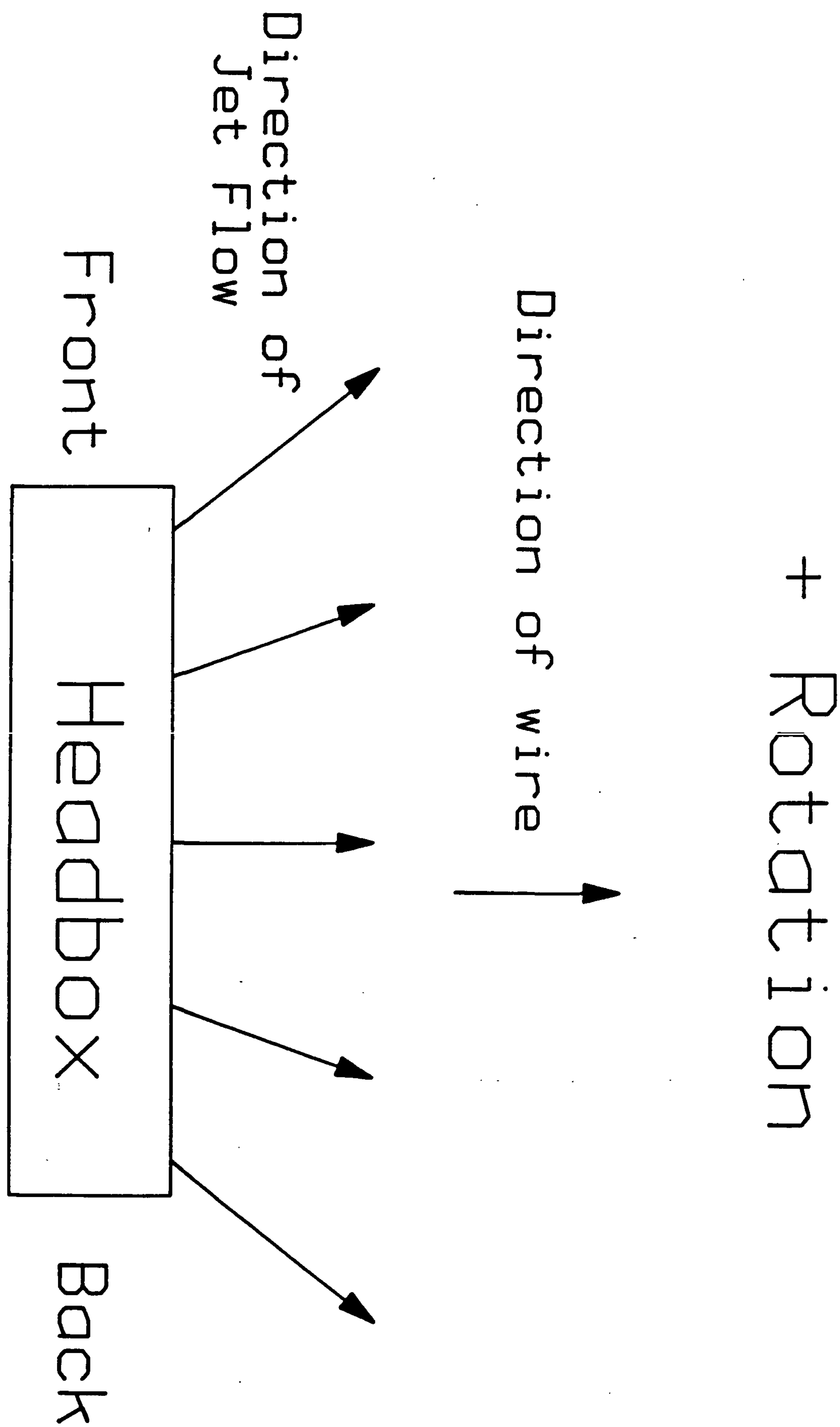

POLAR ANGLE
-2
-1
0
1
2
3
4
5
6
7
8
Front
Center
Back
Translation (t)
CROSS MACHINE POSITION

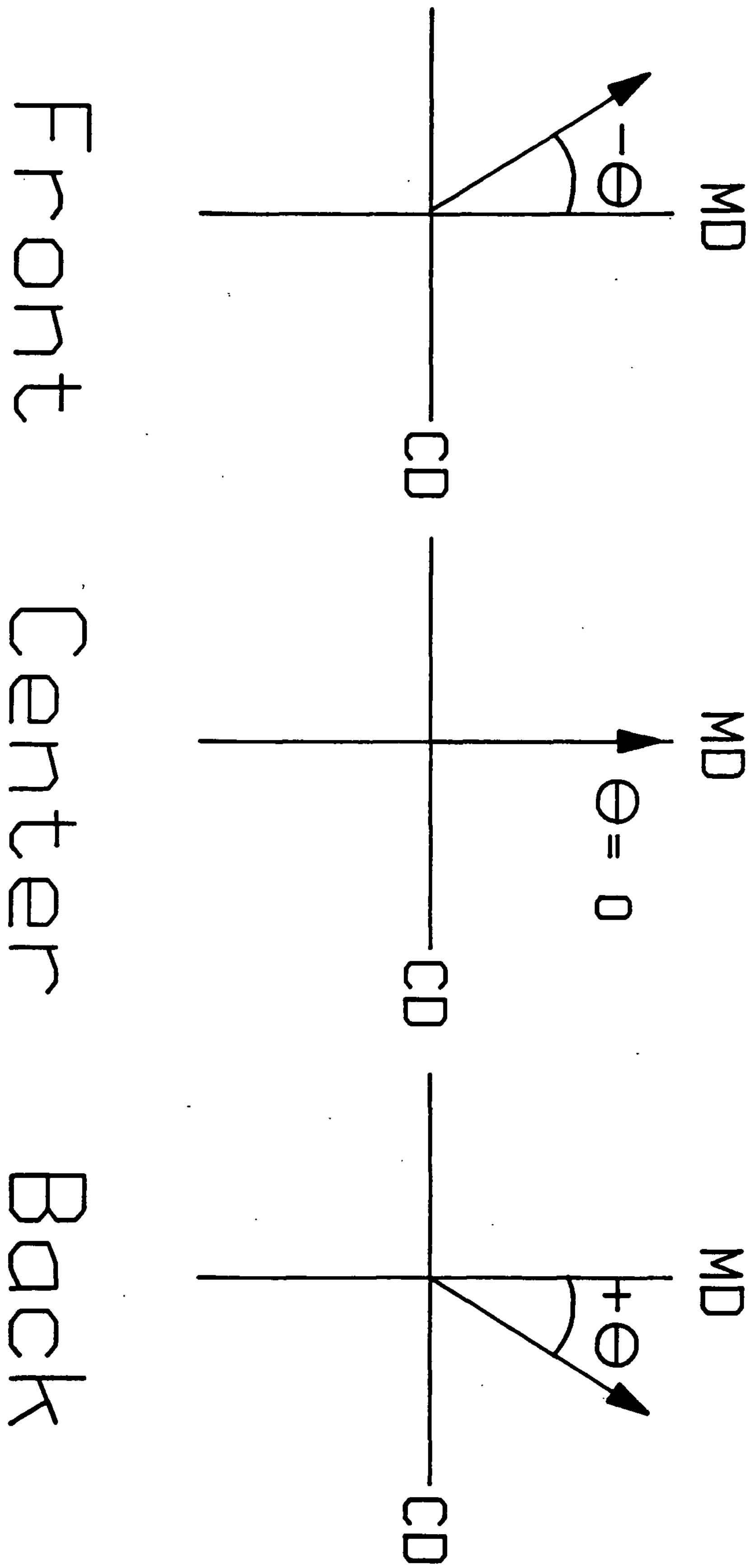
+ Translation




MD
+θ
CD


POLAR ANGLE
-5 -4 -3 -2 -1 0 1 2 3 4 5
Front
Center
Back
Rotation (r)
r
CROSS MACHINE POSITION


Direction of Jet Flow
Front
Headbox
Back
Direction of wire
+ Rotation


Front
Center
Back
MD
CD
-θ
θ = 0
+θ

EQUATIONS

Y = MX + B

POLAR ANGLE = M (CROSS REEL POSITION) + B

TRANSLATION = M (CENTER POSITION) + B

ROTATION = ARCTAN (M)

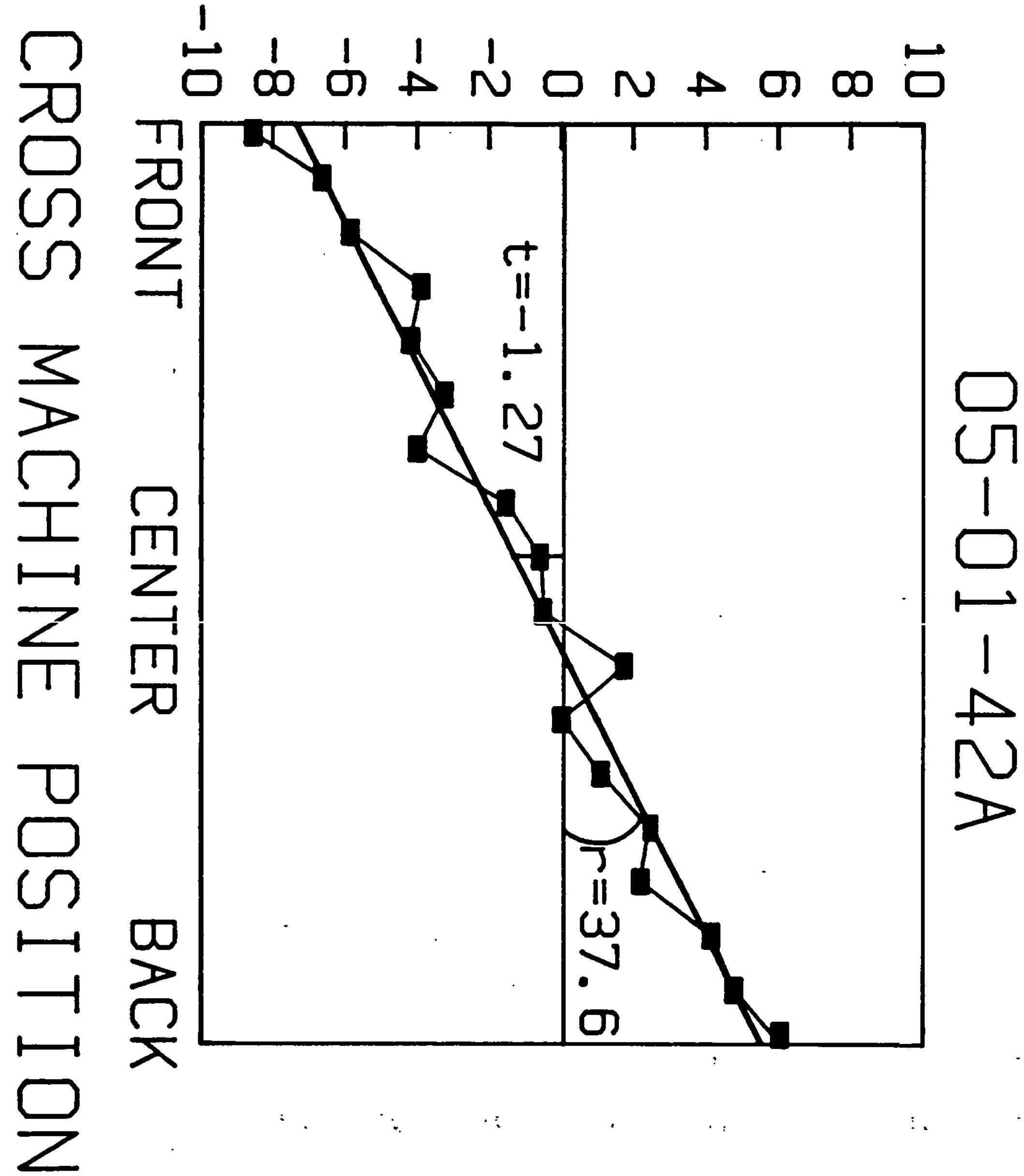
VARIATION = STANDARD DEVIATION

SUMMARY OF RESULTS

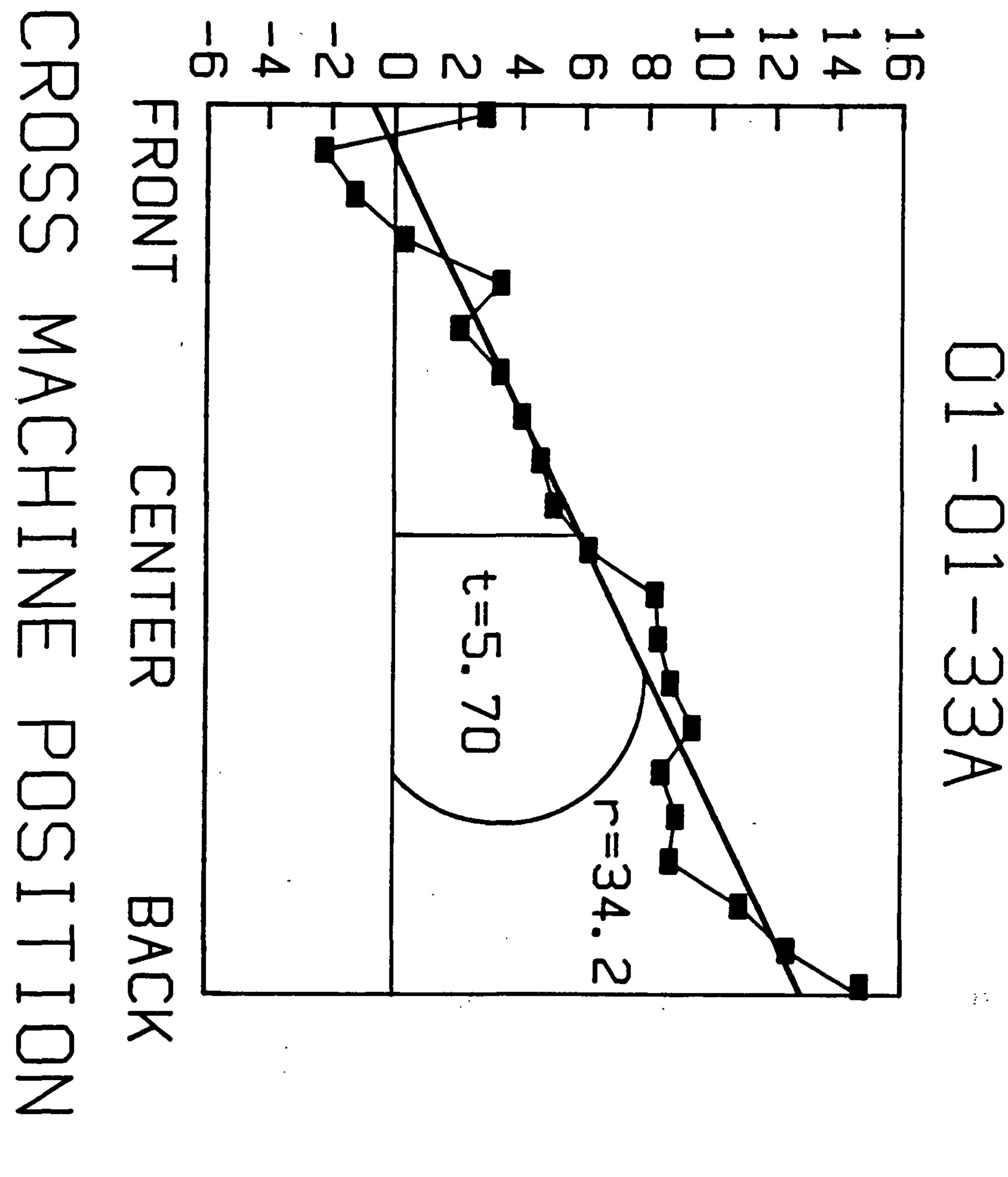
		RANGE	NO. OF MACHINES
TRANSLATION			
	+	0 to +8.2	1 (>5)
	−	0 to −5.3	1 (>5)
ROTATION			
	+	0 to +37.6	7 (>20)
	−	0 to −30.1	2 (>20)
VARIATION			
		0.72 to 2.00	

SAMPLE	TRANSLATION t	ROTATION r	VARIATION sigma
01-01-26A	8.19	33.4	1.21
01-01-33A	5.70	34.2	1.20
05-01-33A	-0.52	33.4	1.30
05-01-42A	-1.27	37.6	0.90
05-01-69A	N.S.	N.S.	2.00
06-01-42A	-5.31	17.2	1.41
06-01-69A	-4.82	20.8	1.49
16-01-26A	1.09	25.6	0.97
16-01-33A	1.89	N.S.	0.99

POLAR ANGLE


05-01-42A
t=-1.27
r=37.6
10
8
6
4
2
0
-2
-4
-6
-8
-10
FRONT
CENTER
BACK
CROSS MACHINE POSITION

POLAR ANGLE

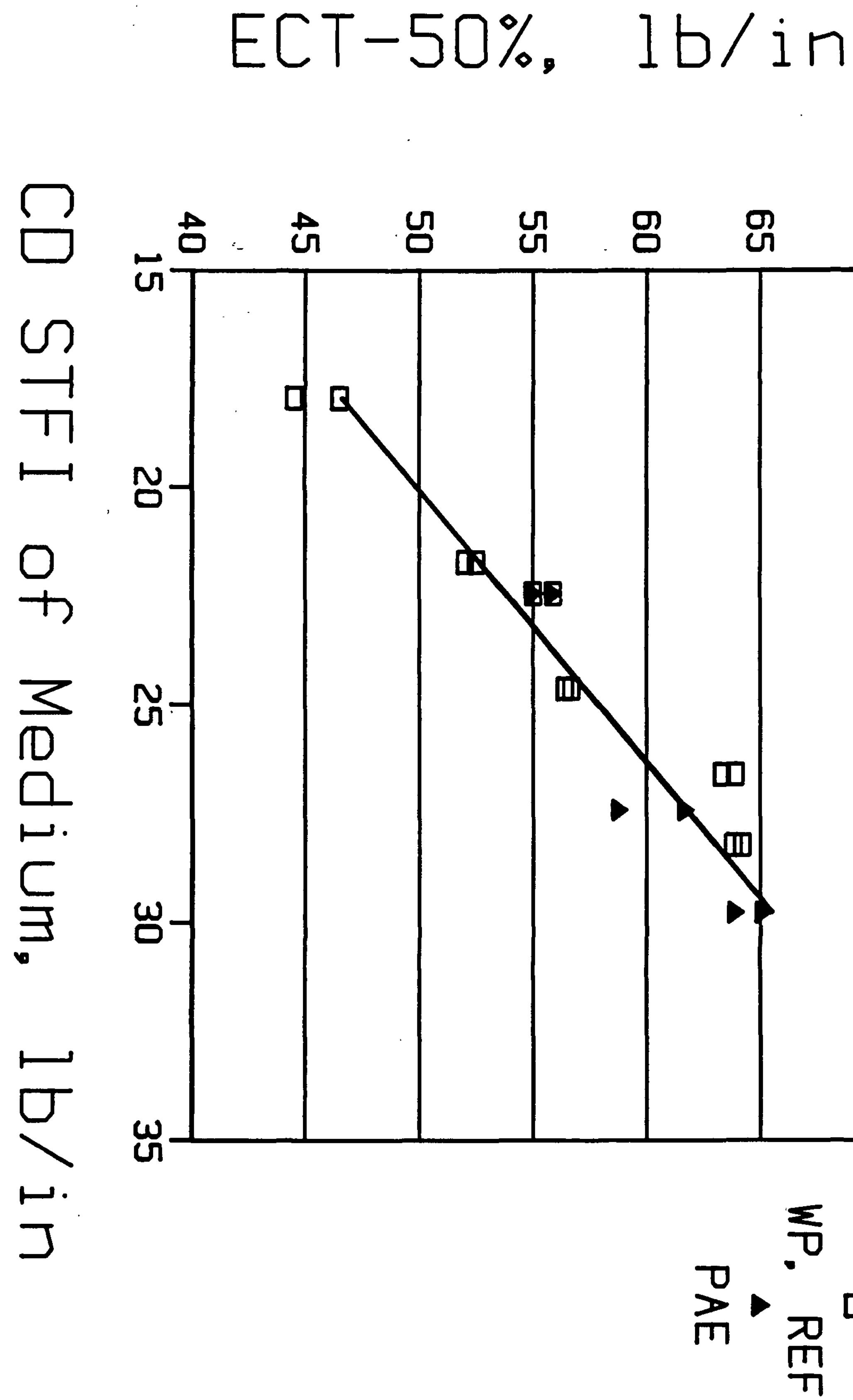


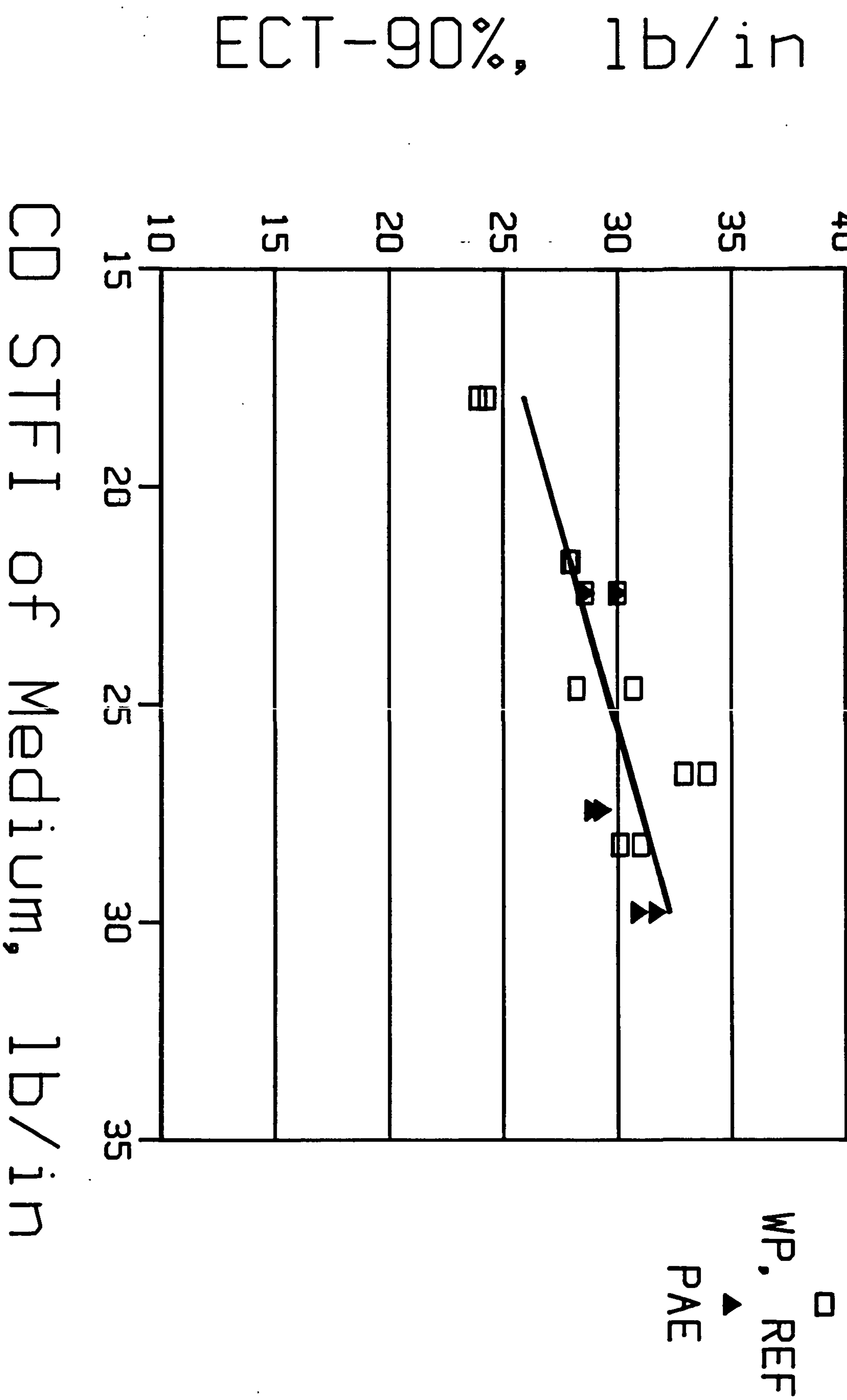
01-01-33A
16
14
12
10
8
6
4
2
0
-2
-4
-6
FRONT
CENTER
BACK
CROSS MACHINE POSITION
t=5.70
r=34.2

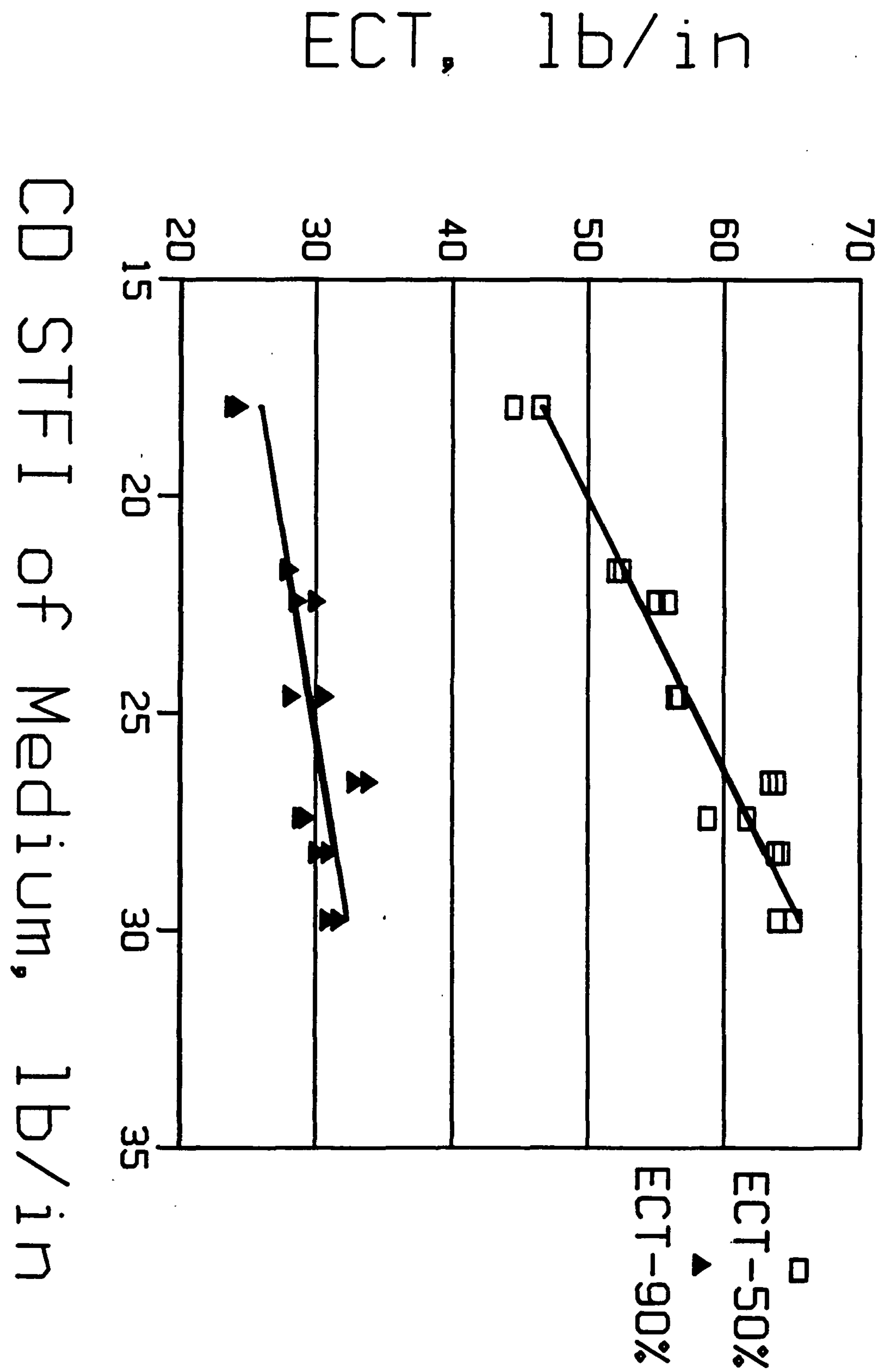
Variables Studied

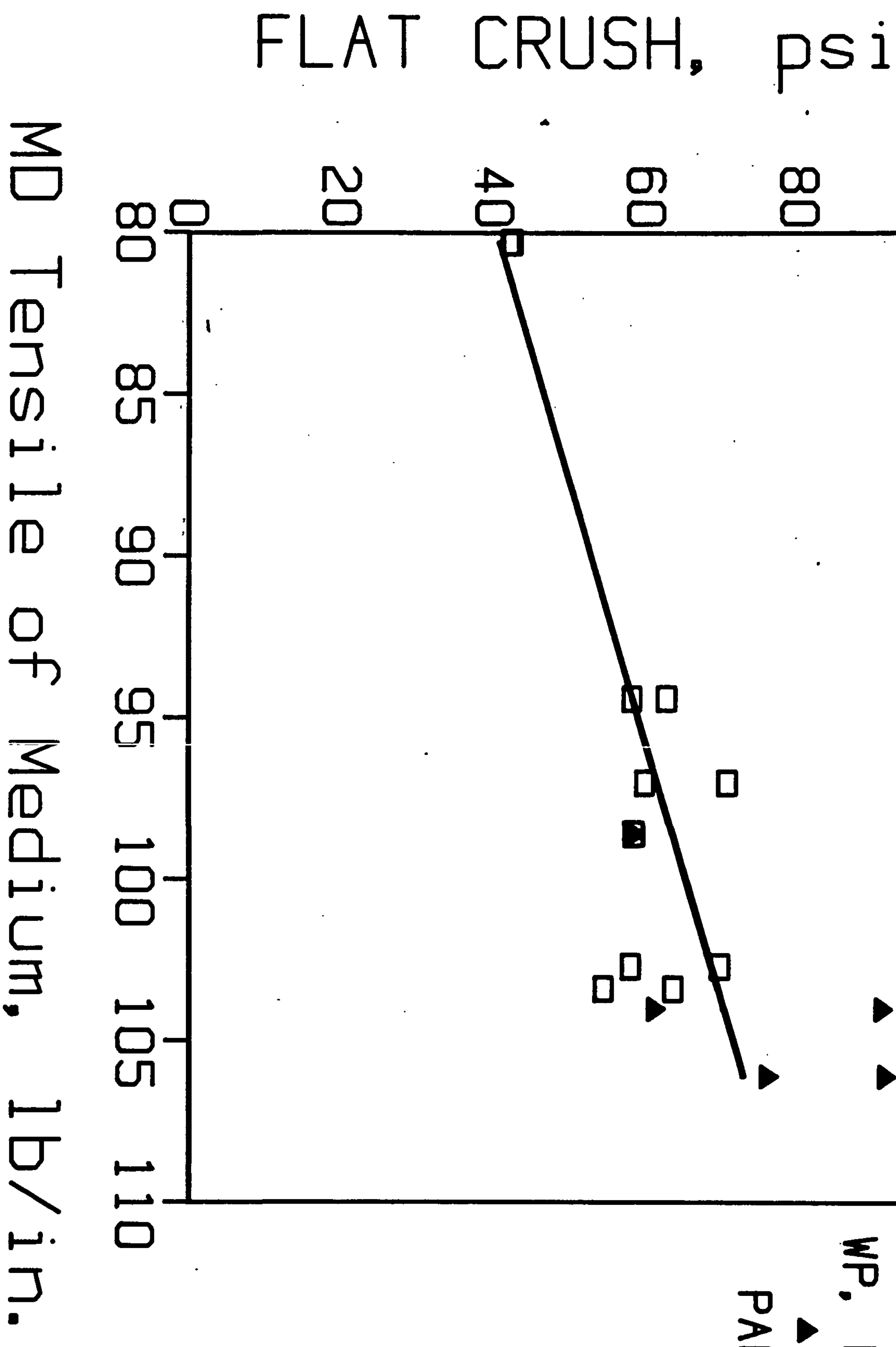
Variable	Level		
Freeness (CSF)	250	325	400
Wet Pressing	L, M	L, M	L,M
Strength Additive (%)[1]		0.5, 1%	
Speed (fpm)	200, 400	200,400	200,400

[1] Additive used at the medium wet pressing level.


ECT-50%, lb/in
40
45
50
55
60
65
70
15
20
25
30
35
CD STFI of Medium, lb/in
WP, REF
PAE


ECT-90%, lb/in
10
15
20
25
30
35
40
15
20
25
30
35
CD STFI of Medium, lb/in
WP, REF
PAE


ECT, lb/in
20
30
40
50
60
70
15
20
25
30
35
CD STFI of Medium, lb/in
ECT-50%
ECT-90%


FLAT CRUSH, psi
0
20
40
60
80
100
80
85
90
95
100
105
110
MD Tensile of Medium, lb/in.
WP, REF
PAE

FUNDAMENTALS OF PAPER SURFACE WETTABILITY

SLIDE MATERIAL

FOR

PROJECT 3646

TO THE

PAPER PROPERTIES AND USES

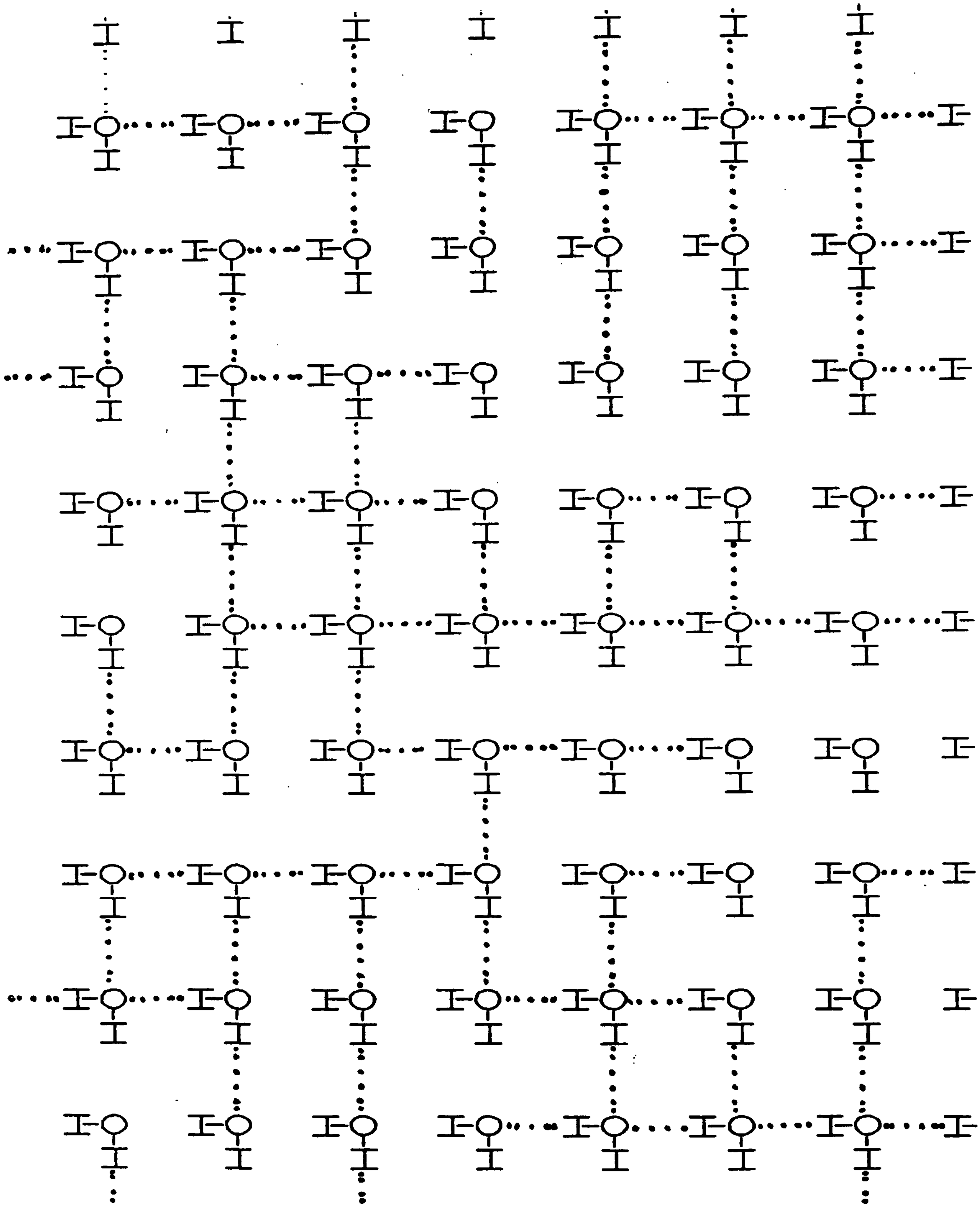
PROJECT ADVISORY COMMITTEE

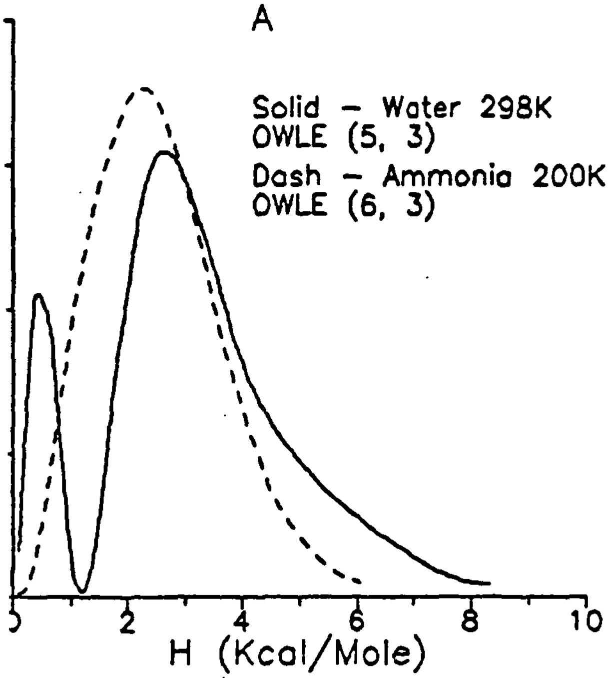
March 21, 1990

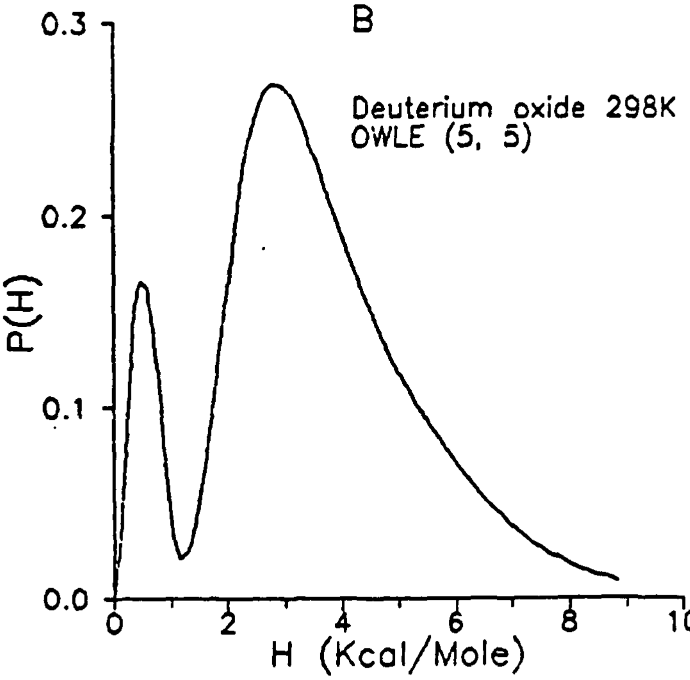
Heat Capacities of Water near a Variety of Surfaces at 25°C

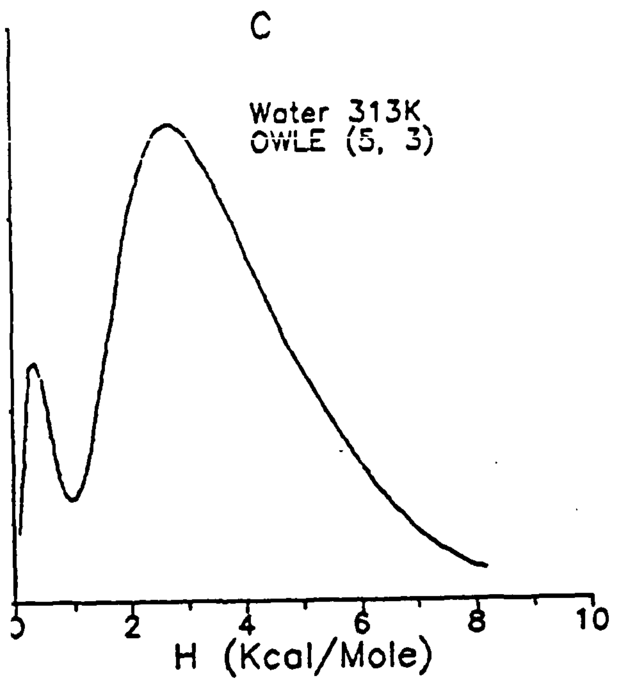
Substance	Heat capacity (cal/g°K)
Bulk water	1.00 ± 0.08
Porous glass	1.27 ± 0.20
Activated carbon	1.28 ± 0.03
Zeolite	1.21 ± 0.03
Diamond	1.20 ± 0.08
Collagen[a]	1.24
Egg albumin[a]	1.25 ± 0.02
DNA[a]	1.26 ± 0.06
Artemia cysts[a]	1.28 ± 0.07

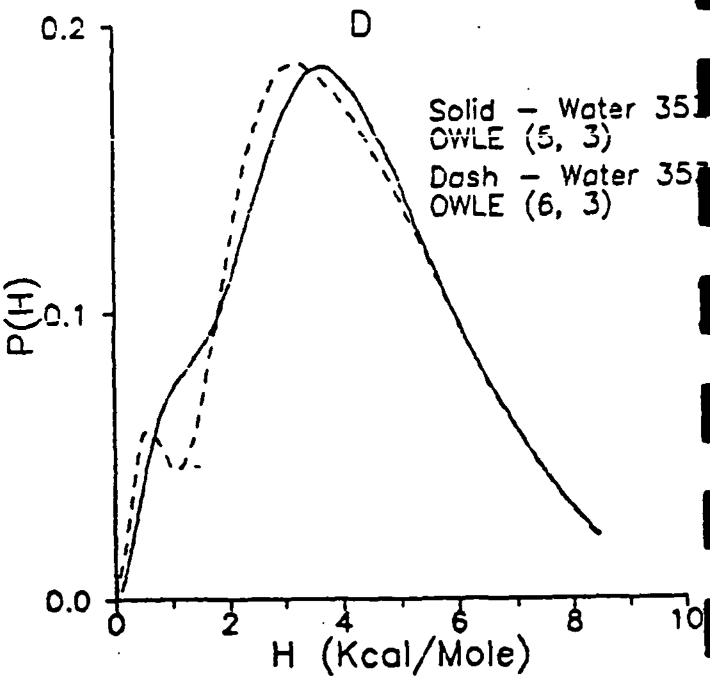
[a] See references listed in (10).




A
Solid – Water 298K
OWLE (5, 3)
Dash – Ammonia 200K
OWLE (6, 3)
2 4 6 8 10
H (Kcal/Mole)


B
Deuterium oxide 298K
OWLE (5, 5)
0.3
0.2
0.1
0.0
P(H)
0 2 4 6 8 10
H (Kcal/Mole)


C
Water 313K
OWLE (5, 3)
2 4 6 8 10
H (Kcal/Mole)


D
Solid – Water 35
OWLE (5, 3)
Dash – Water 35
OWLE (6, 3)
0.2
0.1
0.0
P(H)
0 2 4 6 8 10
H (Kcal/Mole)

$$\alpha_p = \sigma^2_{ev} / VRT^2$$

$$C_p = \sigma^2_h / RT^2$$

$$\beta_T = \sigma^2_v / VRT$$

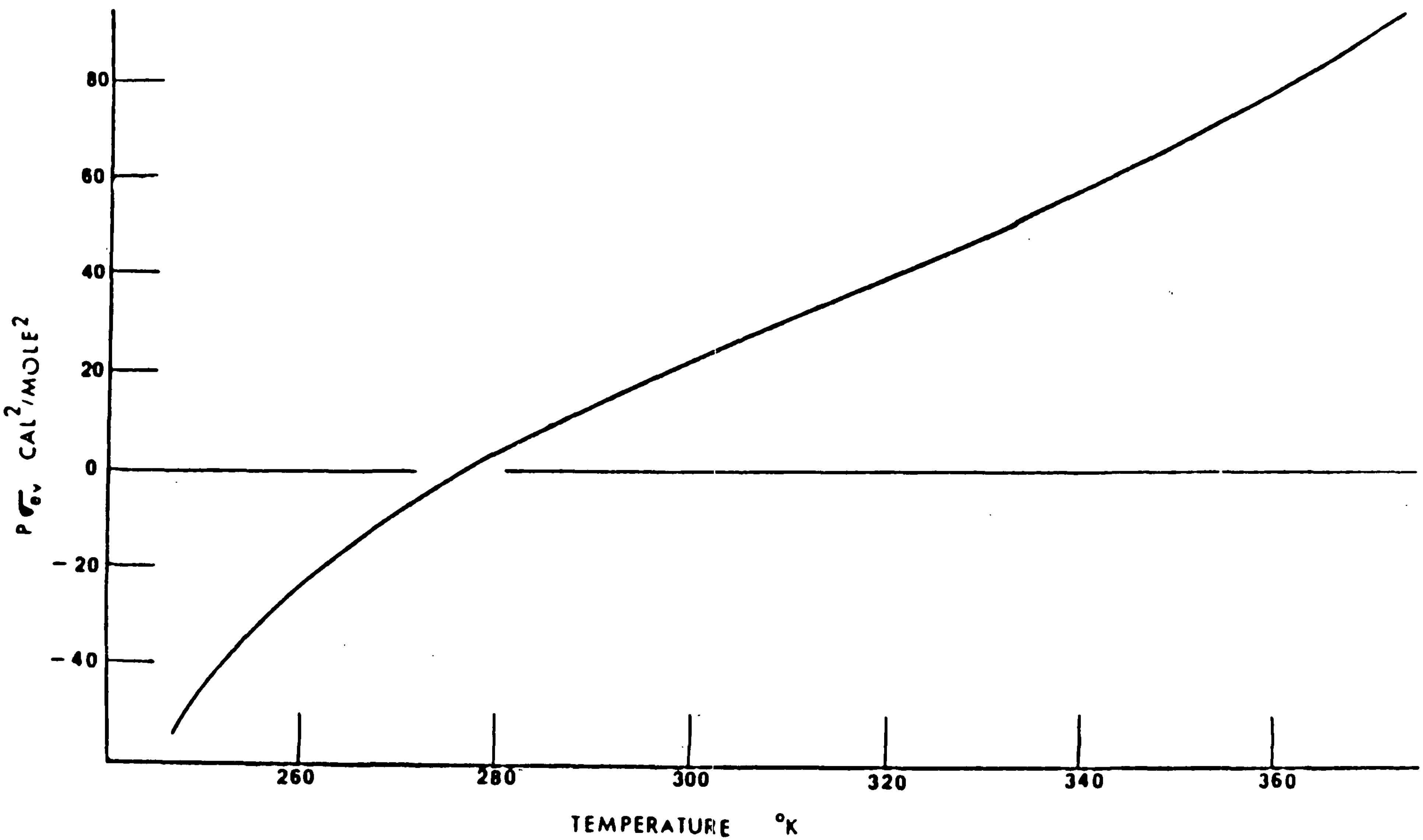
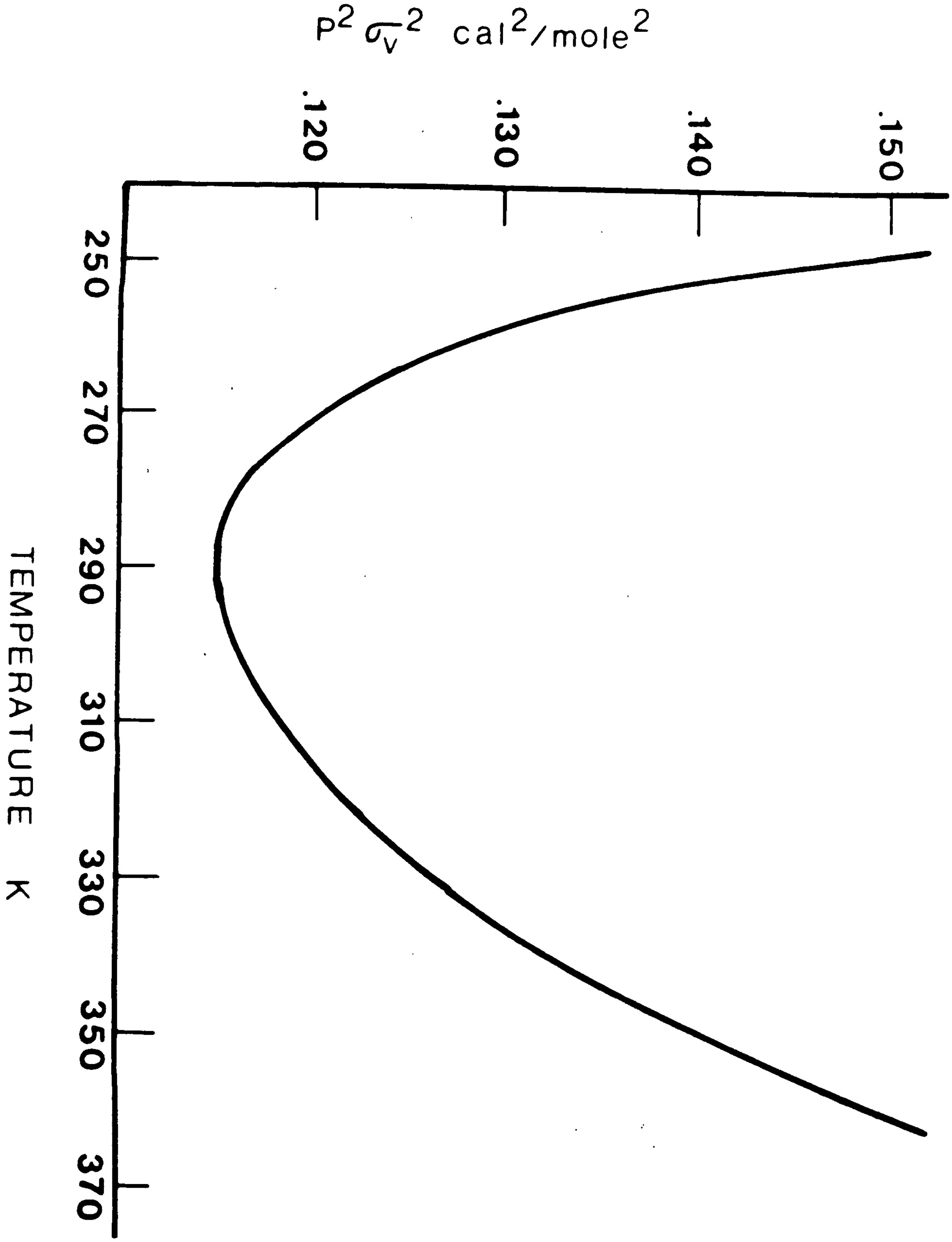
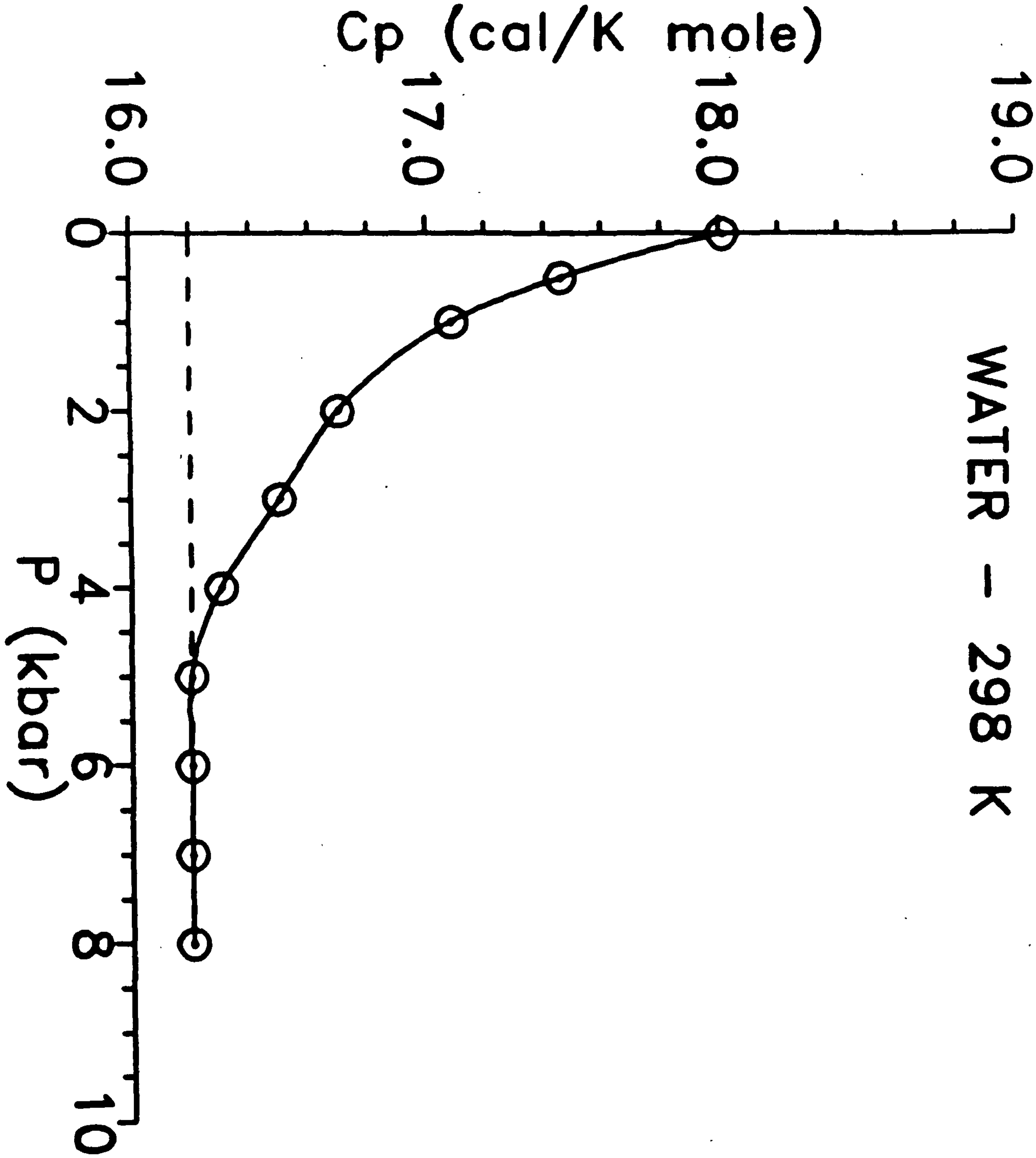


FIG. 8. Covariance between volume and energy for water as a function of temperature, calculated from thermal expansivities by Kell (33). Note negative values below 4°C, suggesting low-energy high-volume states.


$P^2 \sigma_{\bar{V}}^2$ cal^2/mole^2
.120
.130
.140
.150
250
270
290
310
330
350
370
TEMPERATURE K

$$Cp = X_1 Cp_1 + X_2 Cp_2 + X_1 X_2 \left[\frac{\Delta H^2}{R T^2} \right]$$

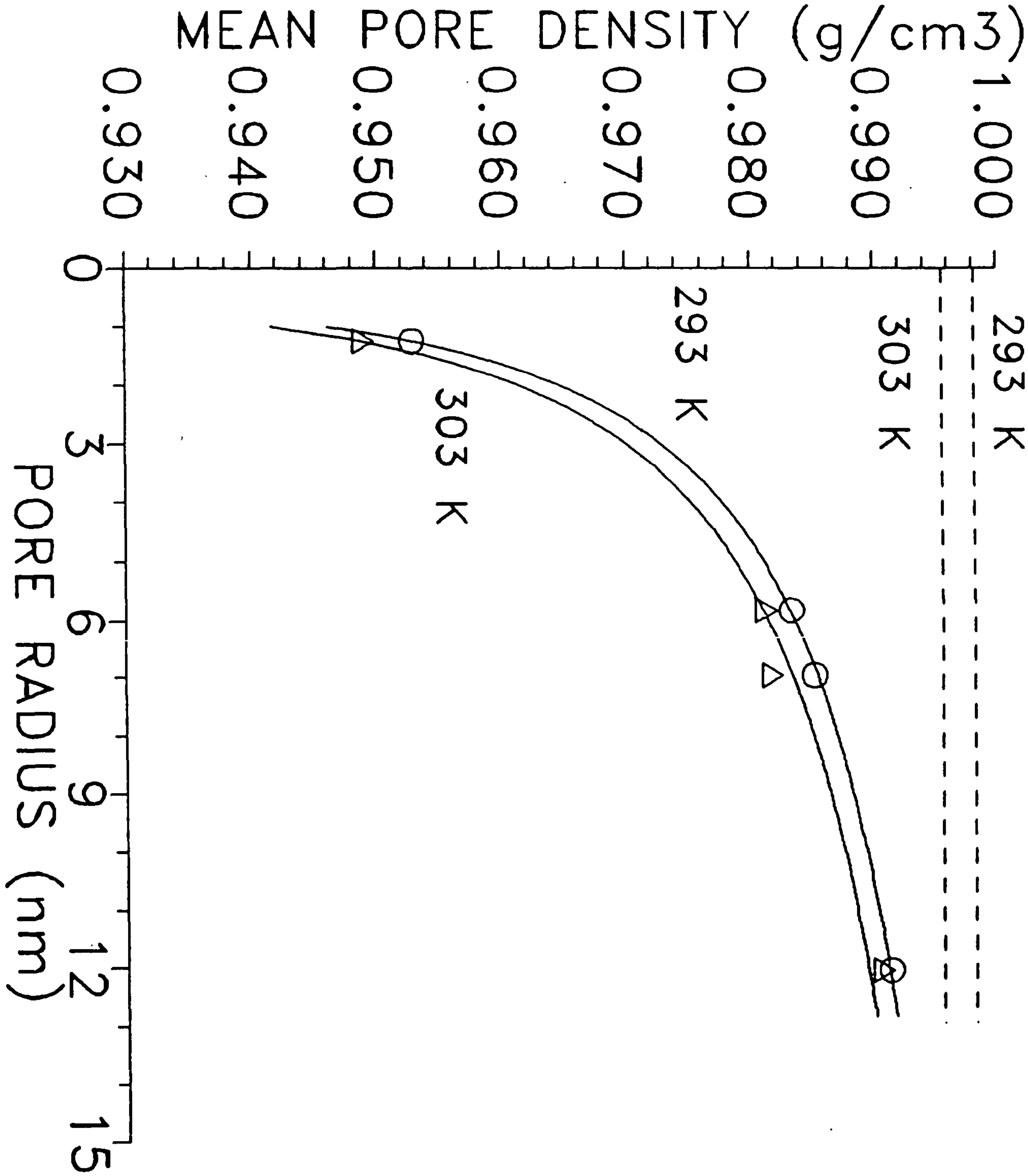
$$\Delta H = H_2 - H_1$$

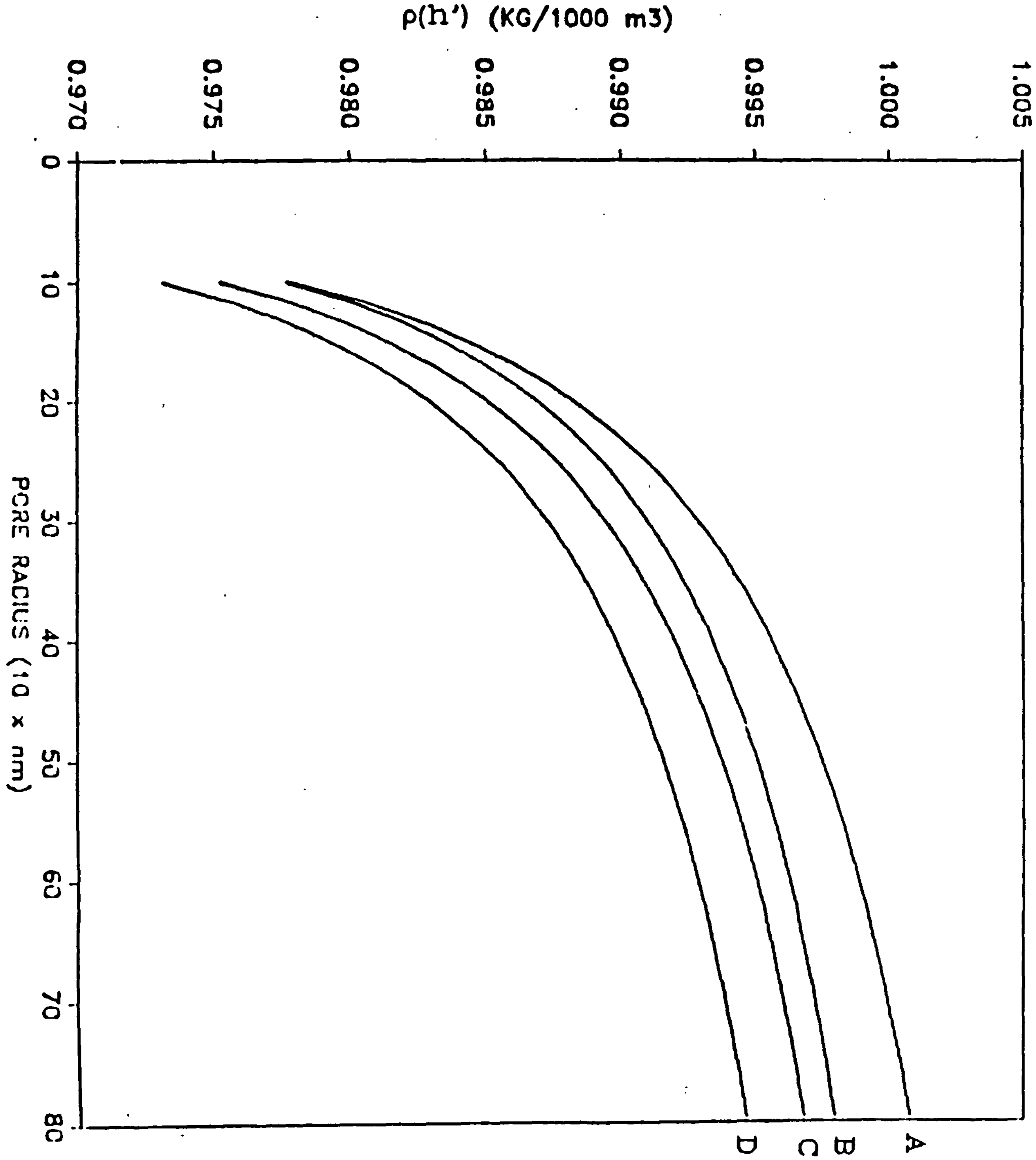

Cp (cal/K mole)
16.0
17.0
18.0
19.0
WATER - 298 K
0
2
4
6
8
10
P (kbar)

FRACTION OF 4-H BONDED MOLECULES AT 25°C

1.	Distribution Function	$\sim$0.1
2.	Stanley and Texeria	0.14
3.	Partial Molar Heat Capacity	0.1

$$V = X_1V_1 + X_2V_2$$


MEAN PORE DENSITY (g/cm3)
0.930
0.940
0.950
0.960
0.970
0.980
0.990
1.000
0
3
6
9
12
15
PORE RADIUS (nm)
293 K
303 K
293 K
303 K


ρ(h') (KG/1000 m3)
0.970
0.975
0.980
0.985
0.990
0.995
1.000
1.005
0
10
20
30
40
50
60
70
80
PORE RADIUS (10 x nm)
A
B
C
D

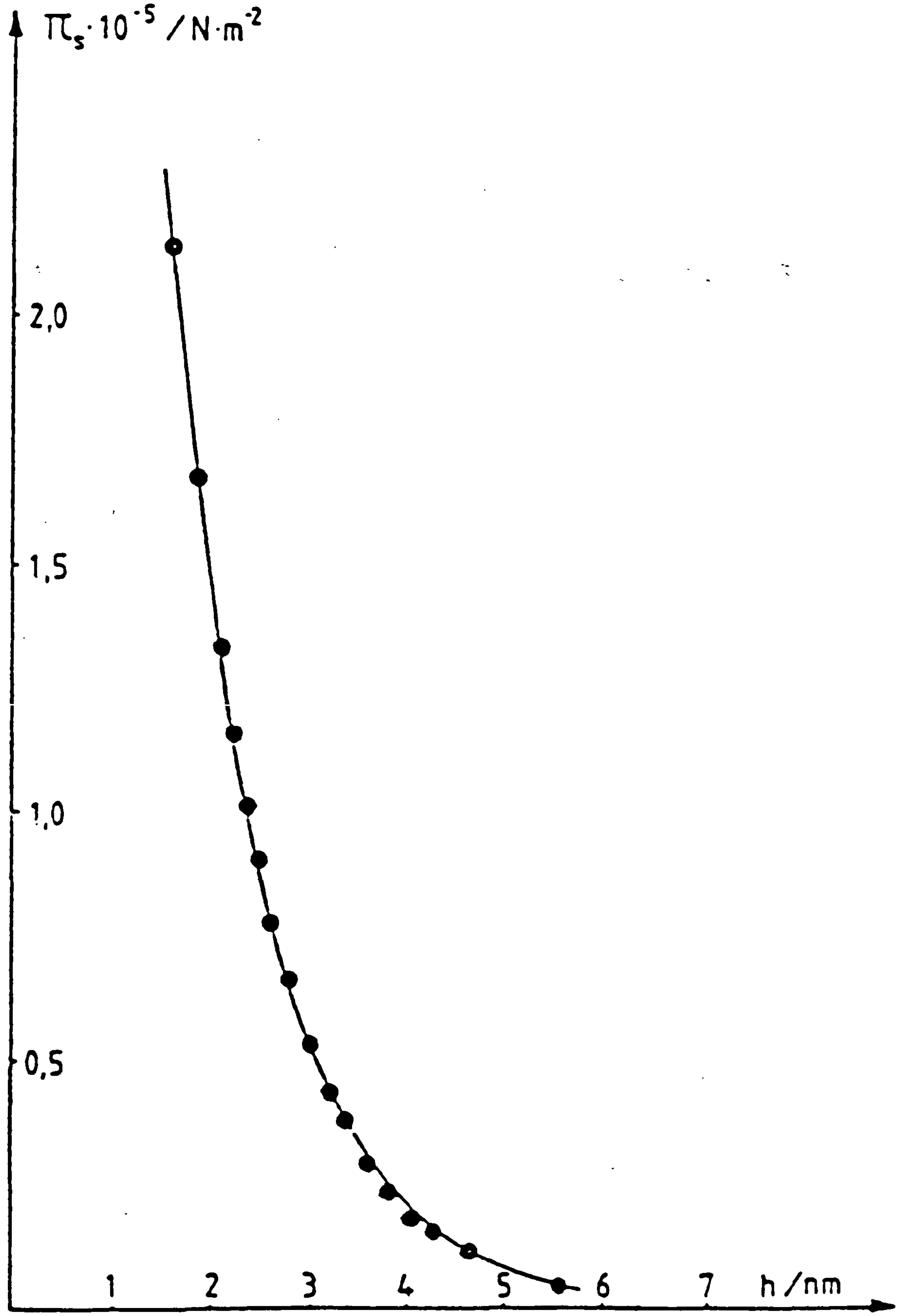
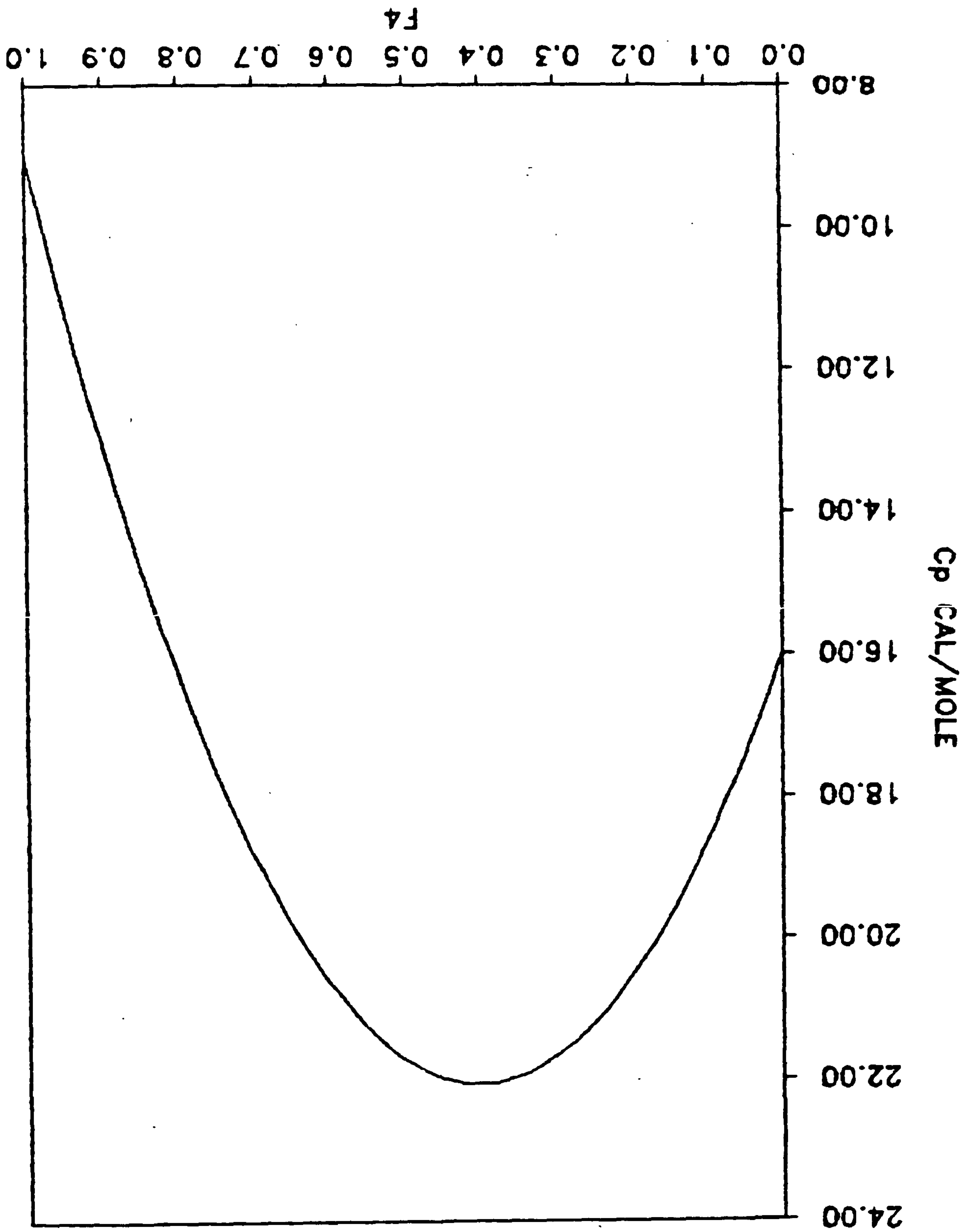
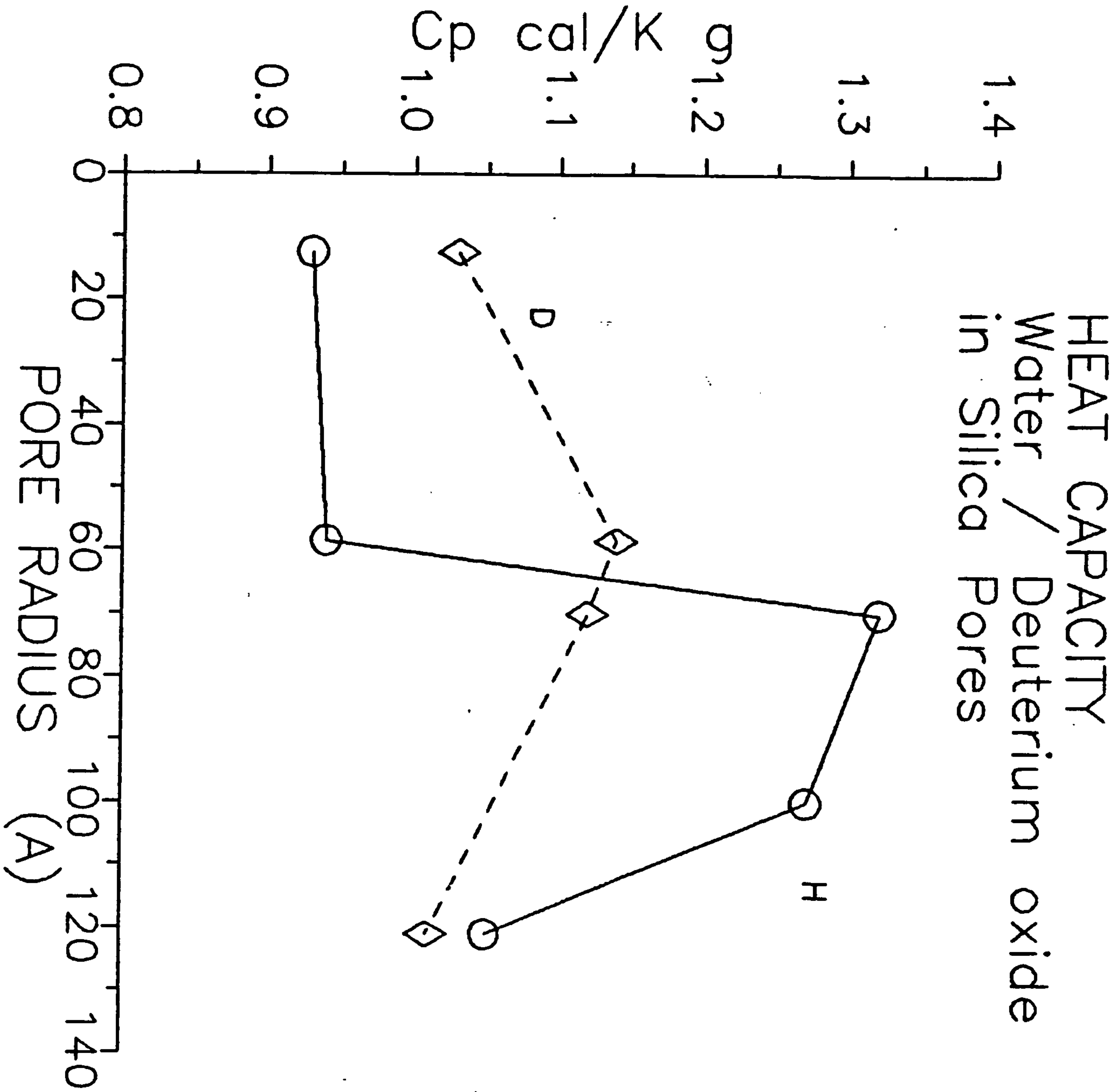
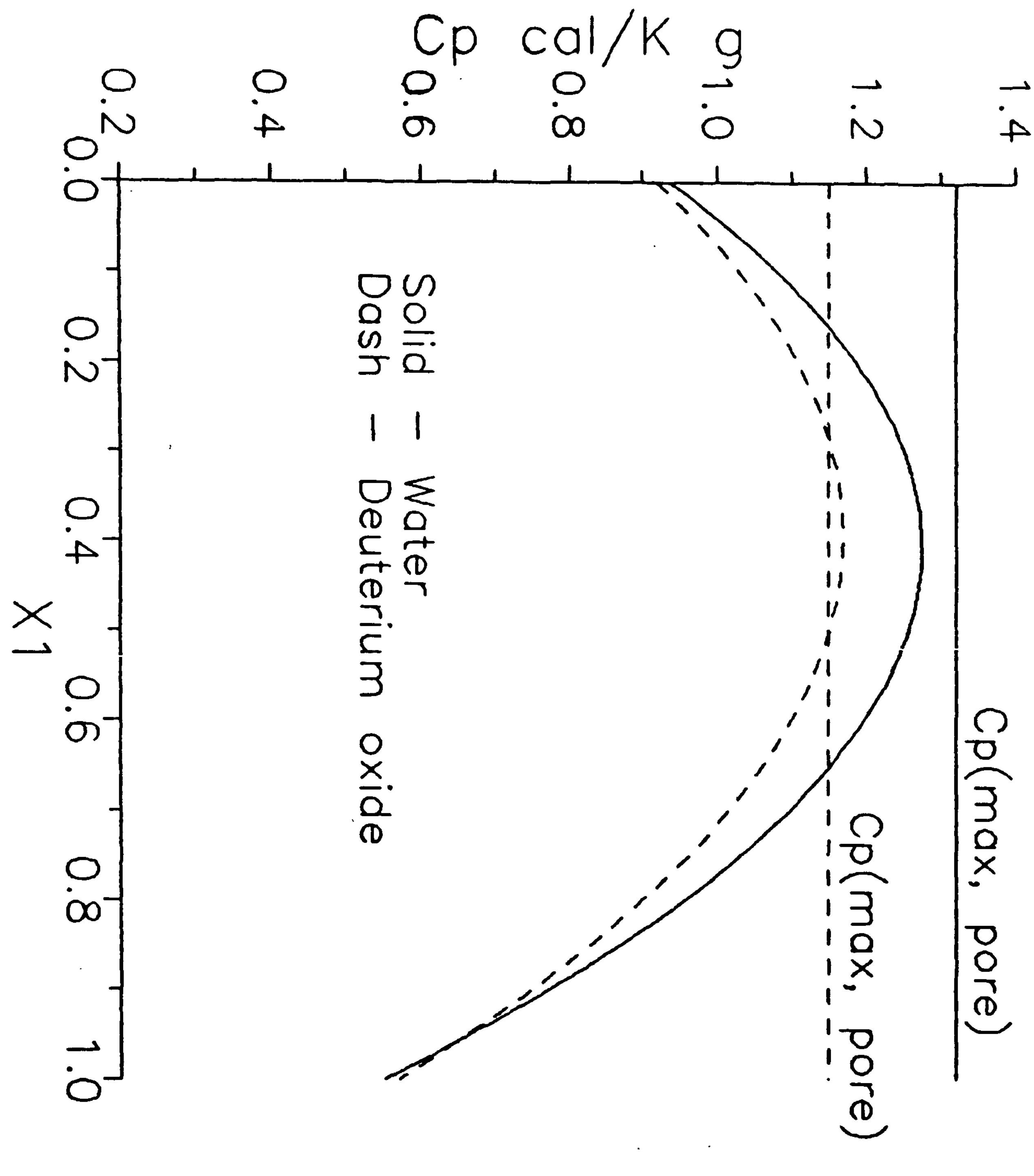


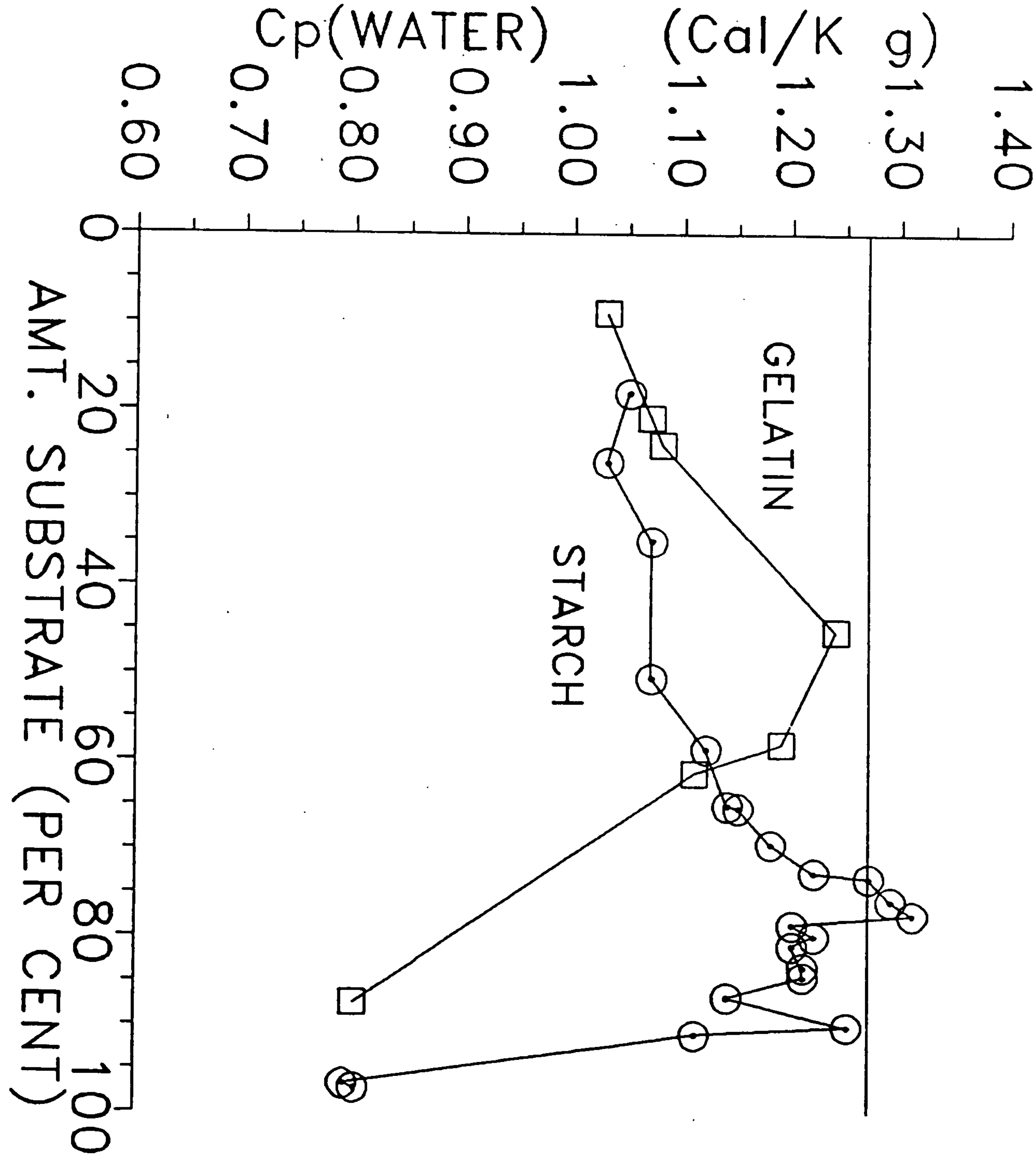
Fig. 3. Additional disjoining pressure component in a thin layer of aqueous 10^{-4} M NaCl solution T = 298 K; pH = 5,4

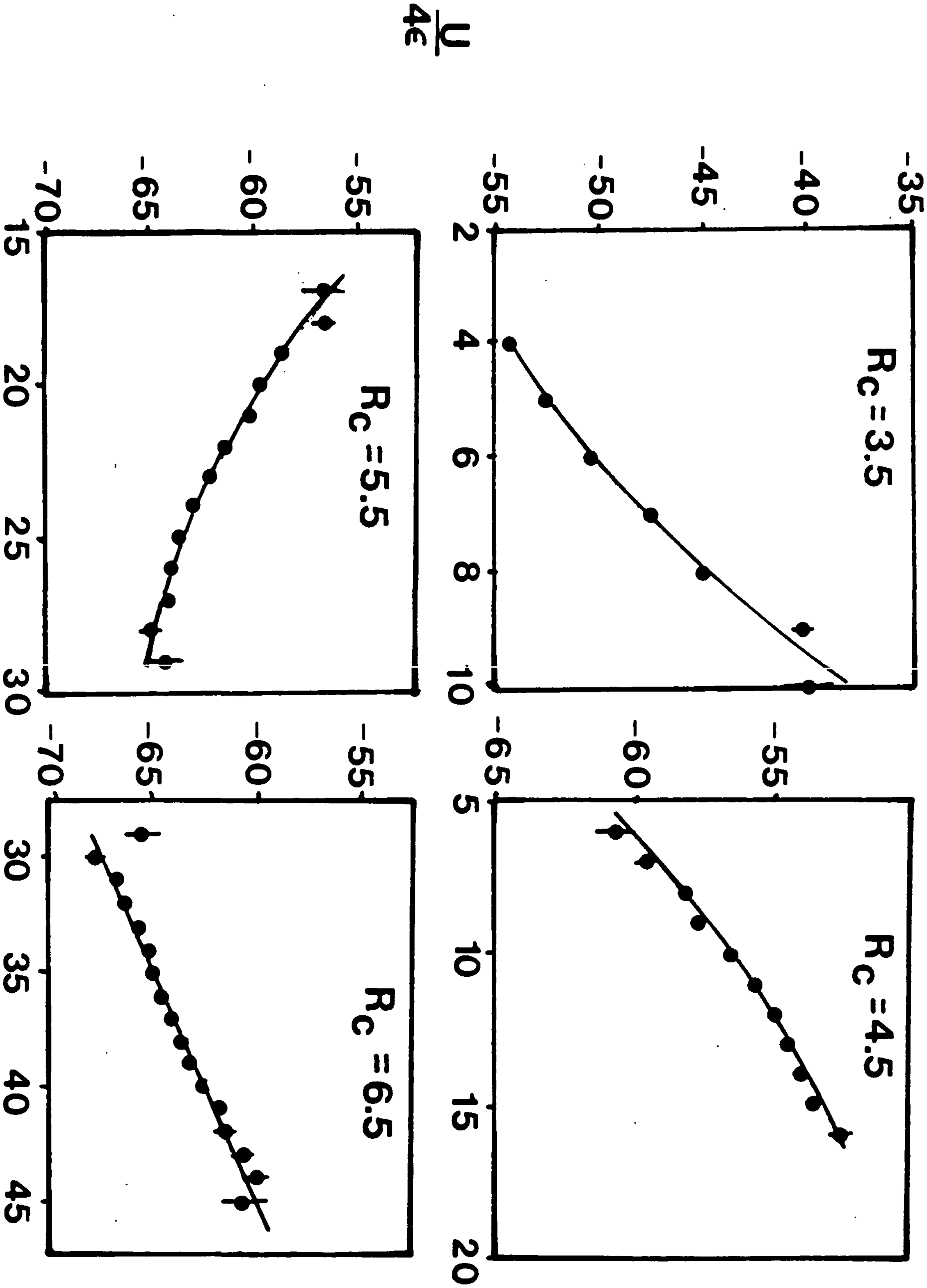
$$C_p = x_1 C_{p1} + x_2 C_{p2} + x_2 x_1 \Delta H^2 / RT^2$$

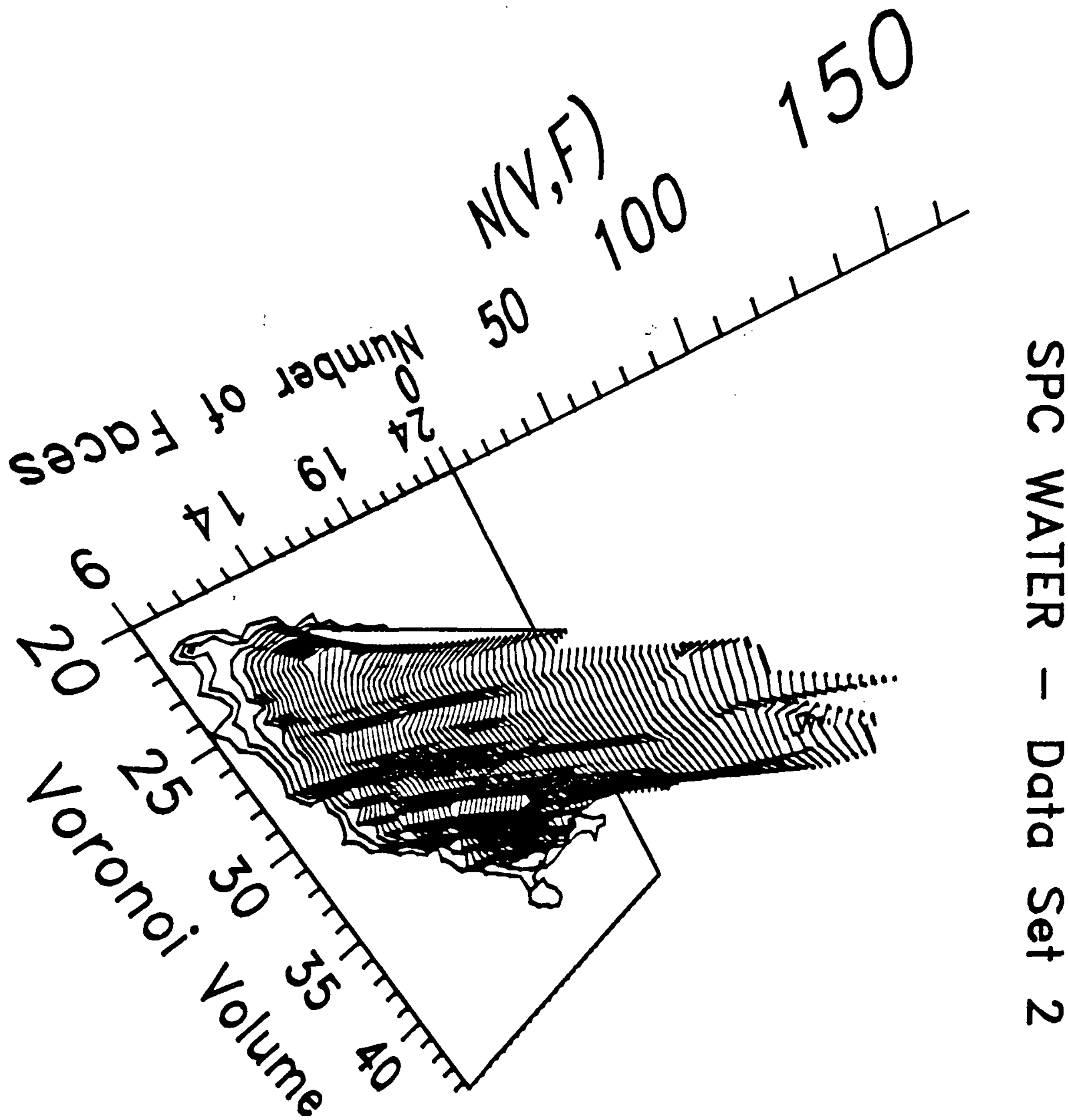

F4
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Cp CAL/MOLE
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00

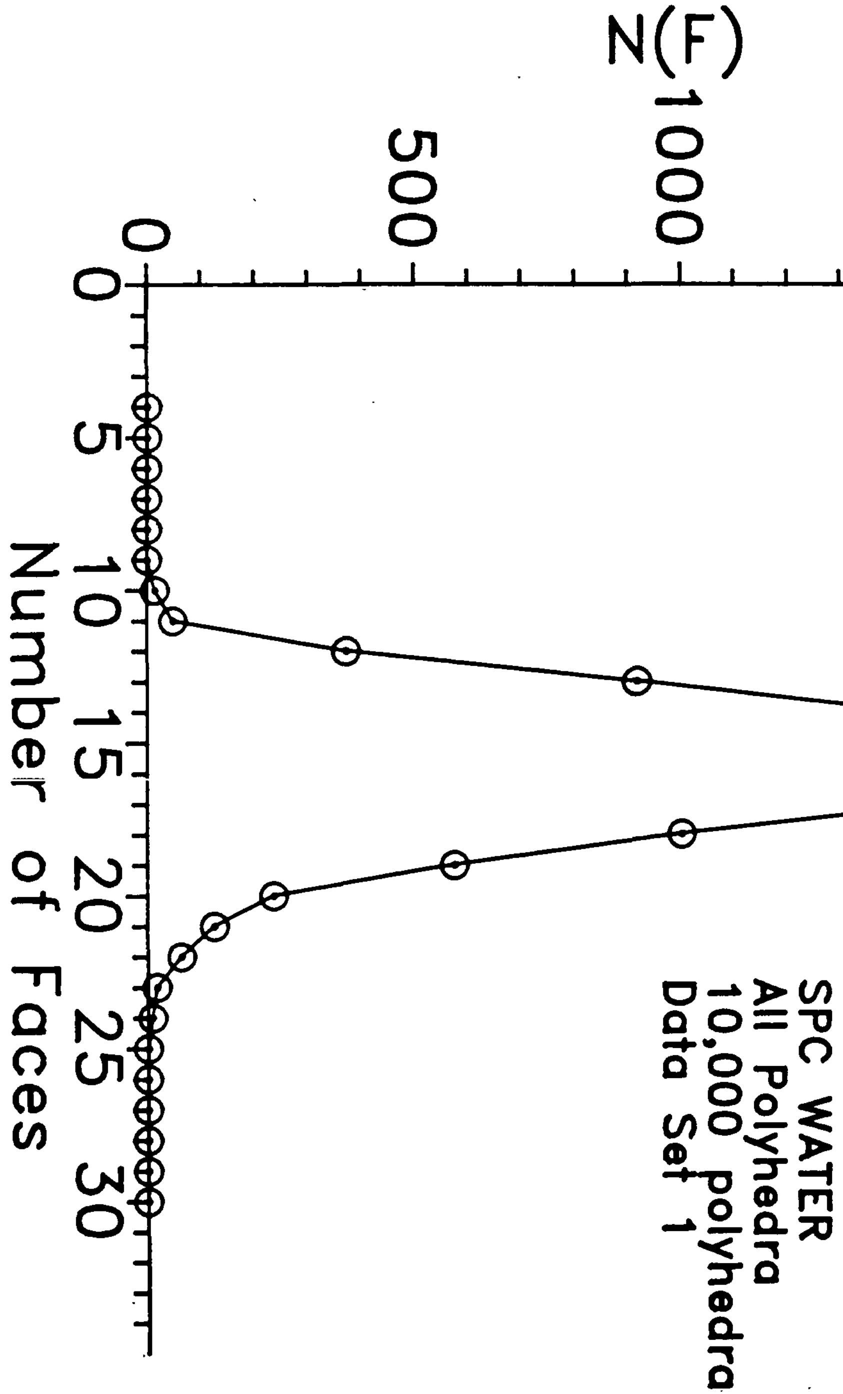

HEAT CAPACITY
Water / Deuterium oxide
in Silica Pores
Cp cal/K g
0.8
0.9
1.0
1.1
1.2
1.3
1.4
0
20
40
60
80
100
120
140
PORE RADIUS (A)
D
H

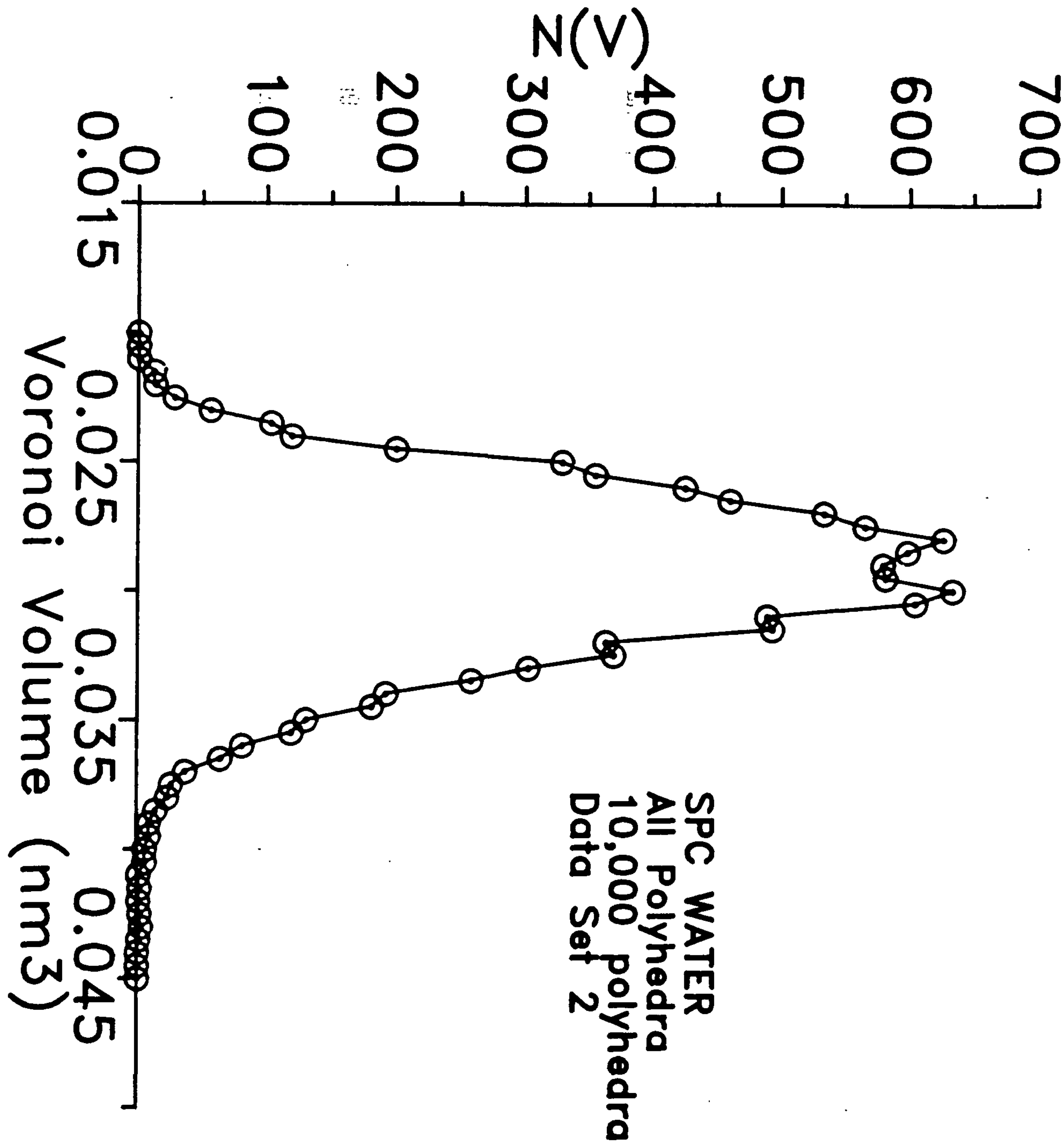

Cp cal/K g
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0.0
0.2
0.4
0.6
0.8
1.0
X1
Solid — Water
Dash — Deuterium oxide
Cp(max, pore)
Cp(max, pore)

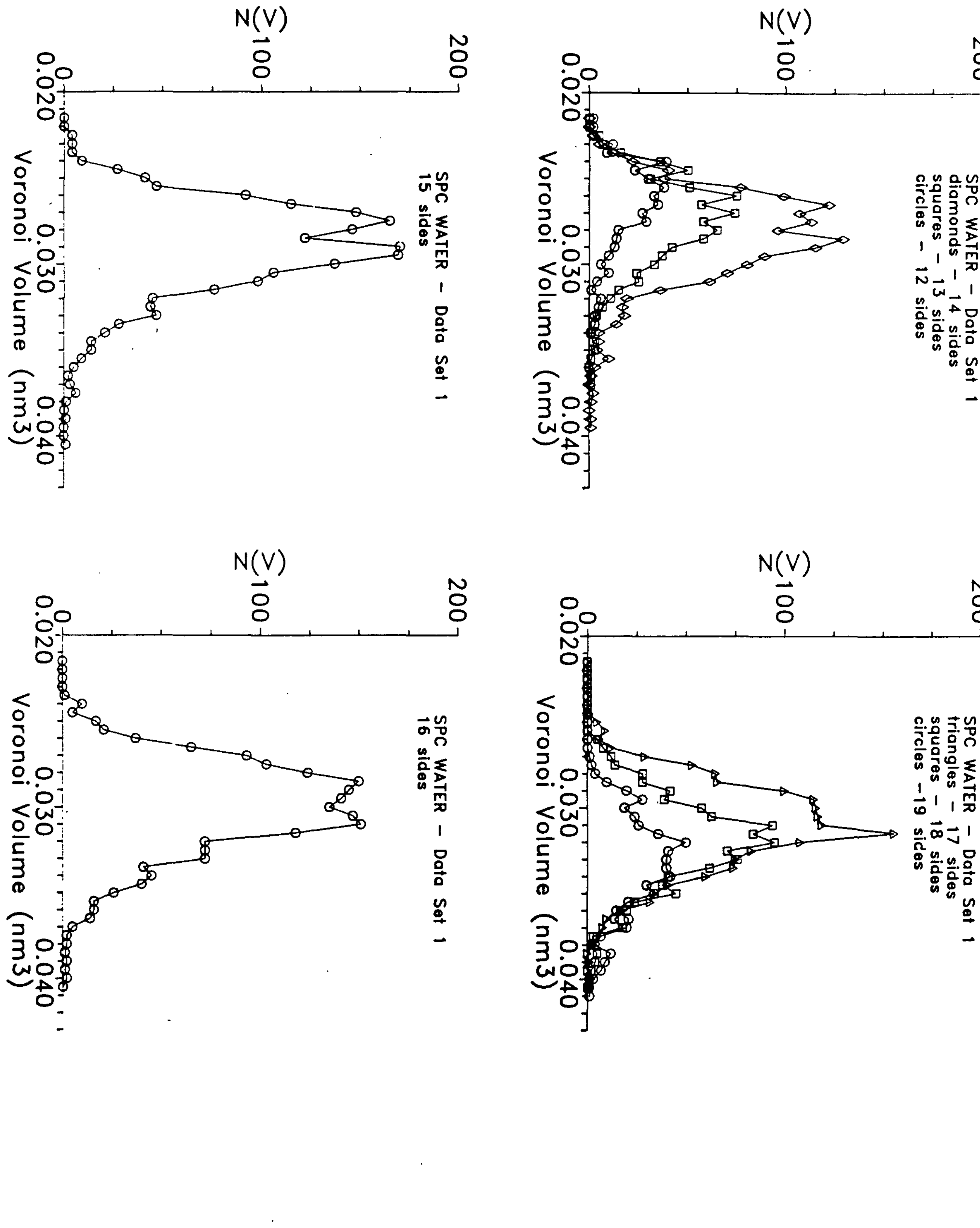

Cp(WATER) (Cal/K g)
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
GELATIN
STARCH
0
20
40
60
80
100
AMT. SUBSTRATE (PER CENT)

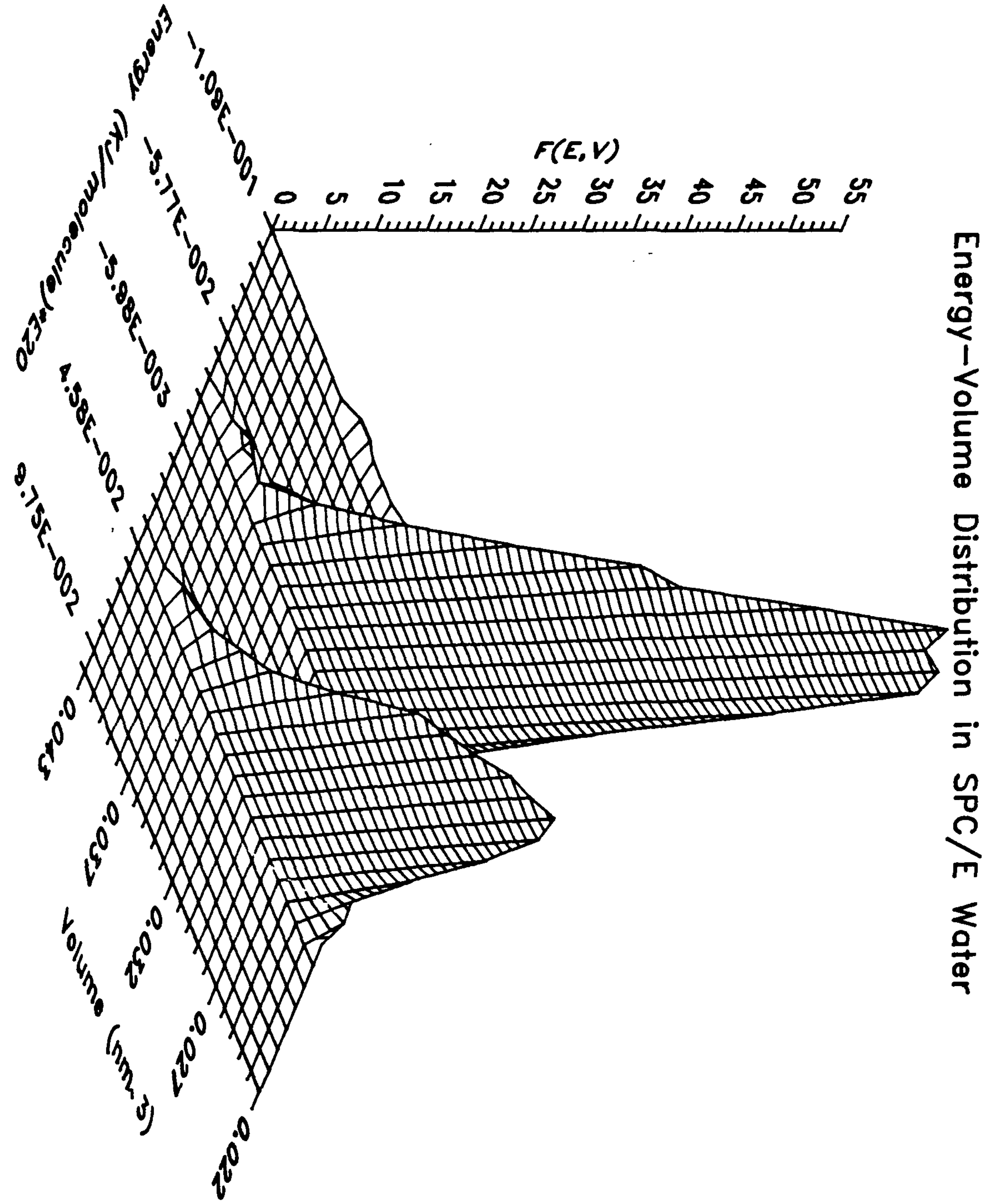

U/4ε
R_c = 3.5
R_c = 4.5
R_c = 5.5
R_c = 6.5
-35
-40
-45
-50
-55
-60
-65
-70
2
4
6
8
10
5
15
20
25
30
35
40
45

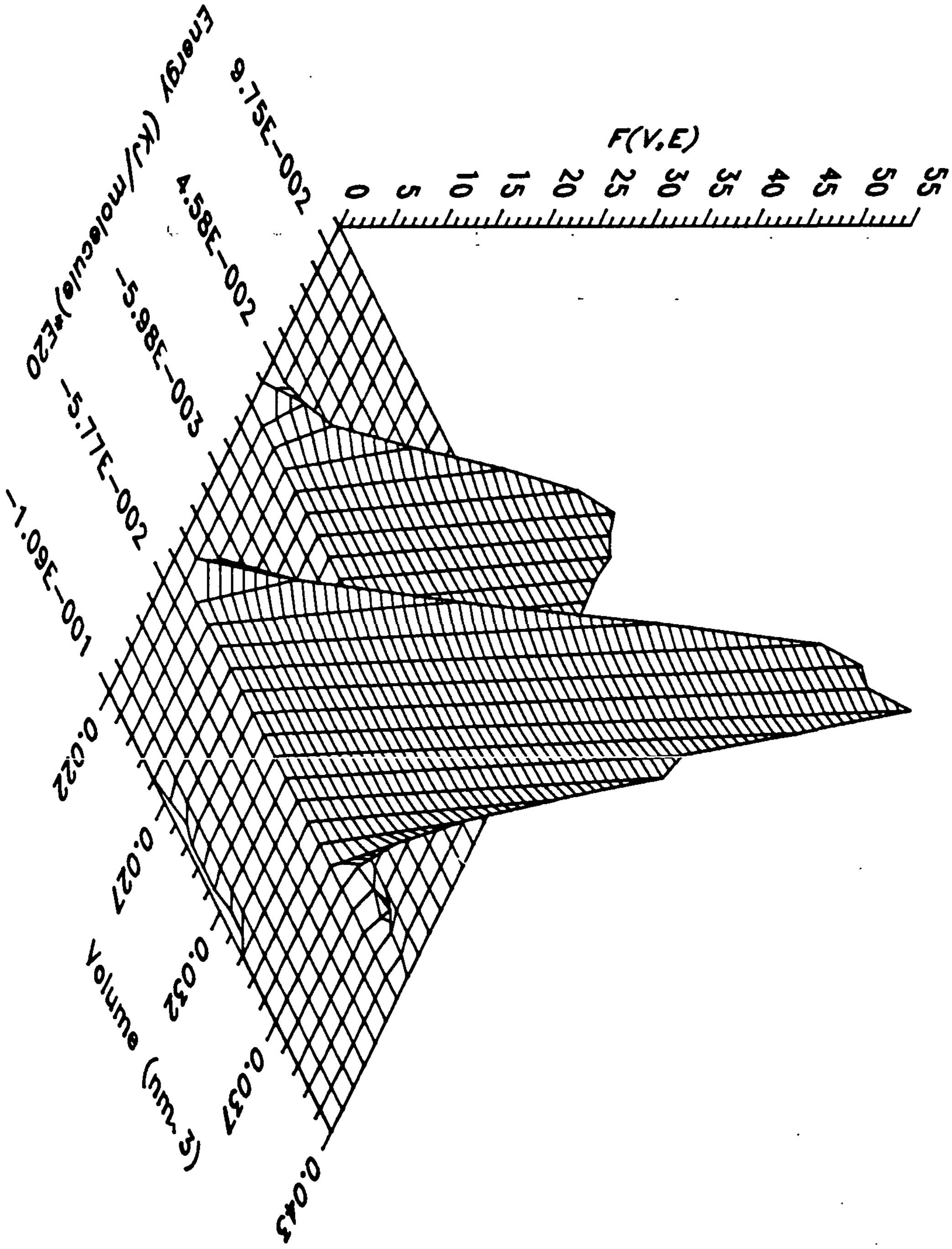

SPC WATER — Data Set 2
N(V,F)
0
50
100
150
Number of Faces
6
14
19
24
Voronoi Volume
20
25
30
35
40


N(F)
2000
1500
1000
500
0
0
5
10
15
20
25
30
Number of Faces
SPC WATER
All Polyhedra
10,000 polyhedra
Data Set 1

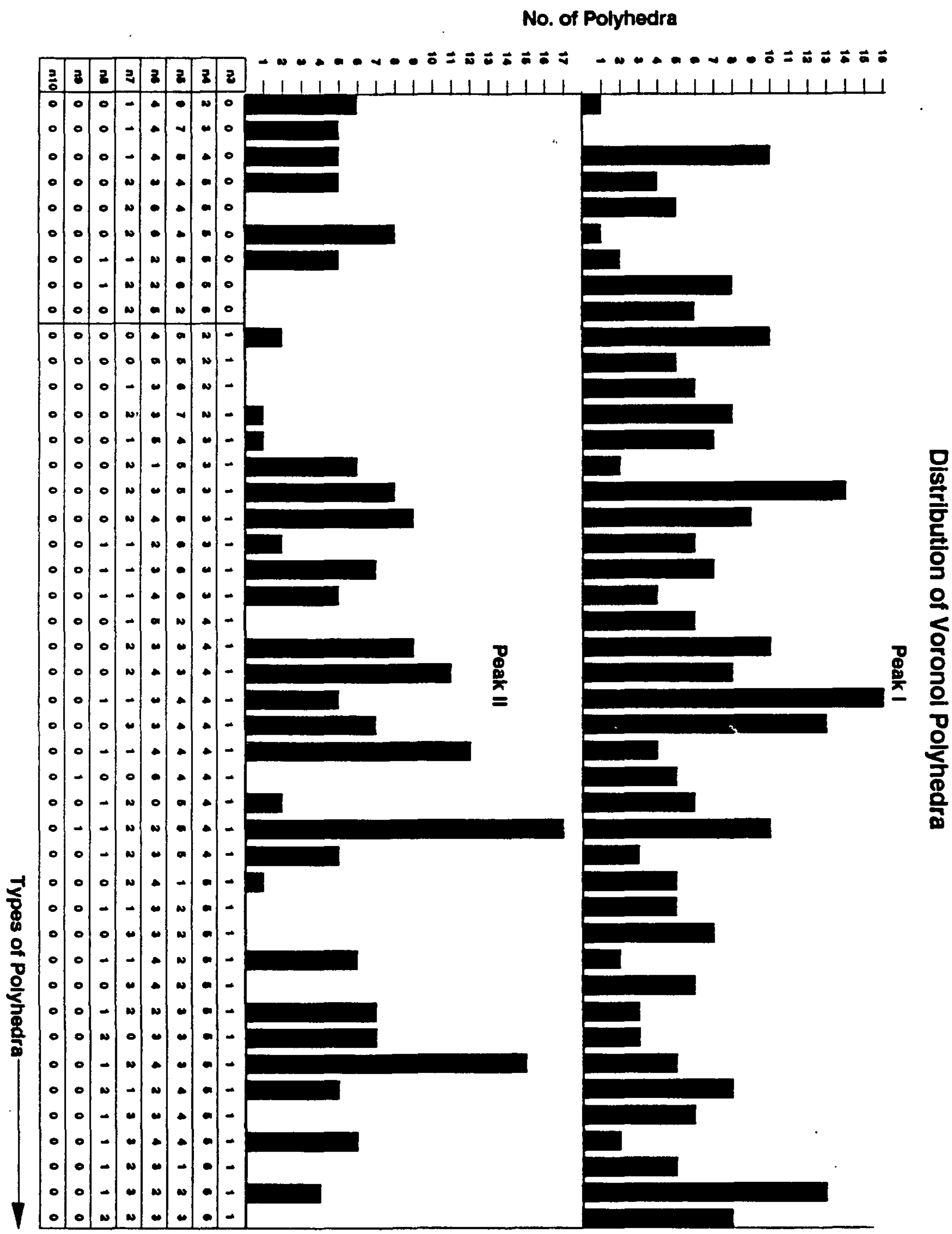

N(V)
0
100
200
300
400
500
600
700
0.015
0.025
0.035
0.045
Voronoi Volume (nm3)
SPC WATER
All Polyhedra
10,000 polyhedra
Data Set 2

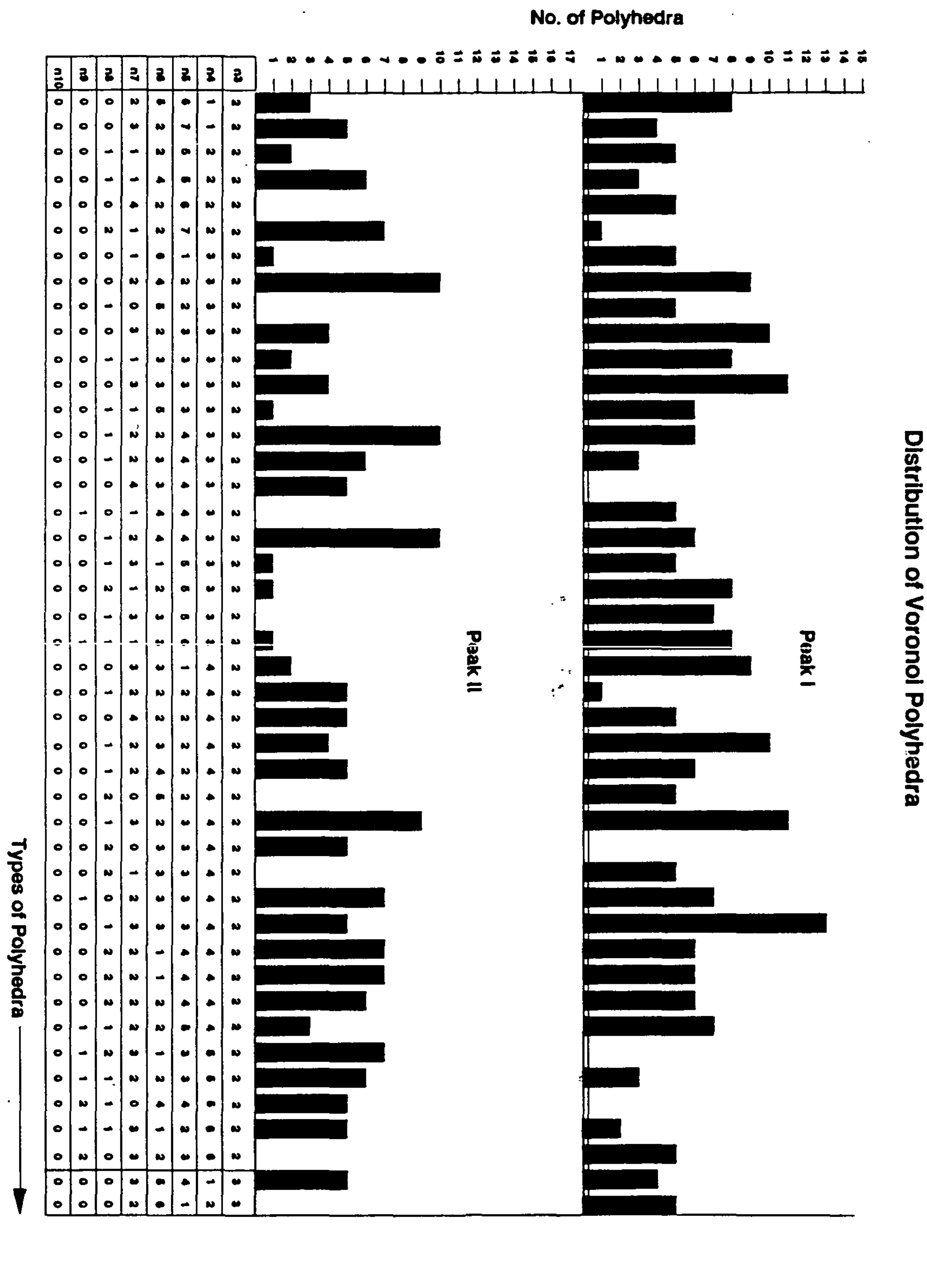

SPC WATER – Data Set 1
diamonds – 14 sides
squares – 13 sides
circles – 12 sides
SPC WATER – Data Set 1
triangles – 17 sides
squares – 18 sides
circles –19 sides
SPC WATER – Data Set 1
15 sides
SPC WATER – Data Set 1
16 sides
N(V)
Voronoi Volume (nm3)
0
100
200
0.020
0.030
0.040

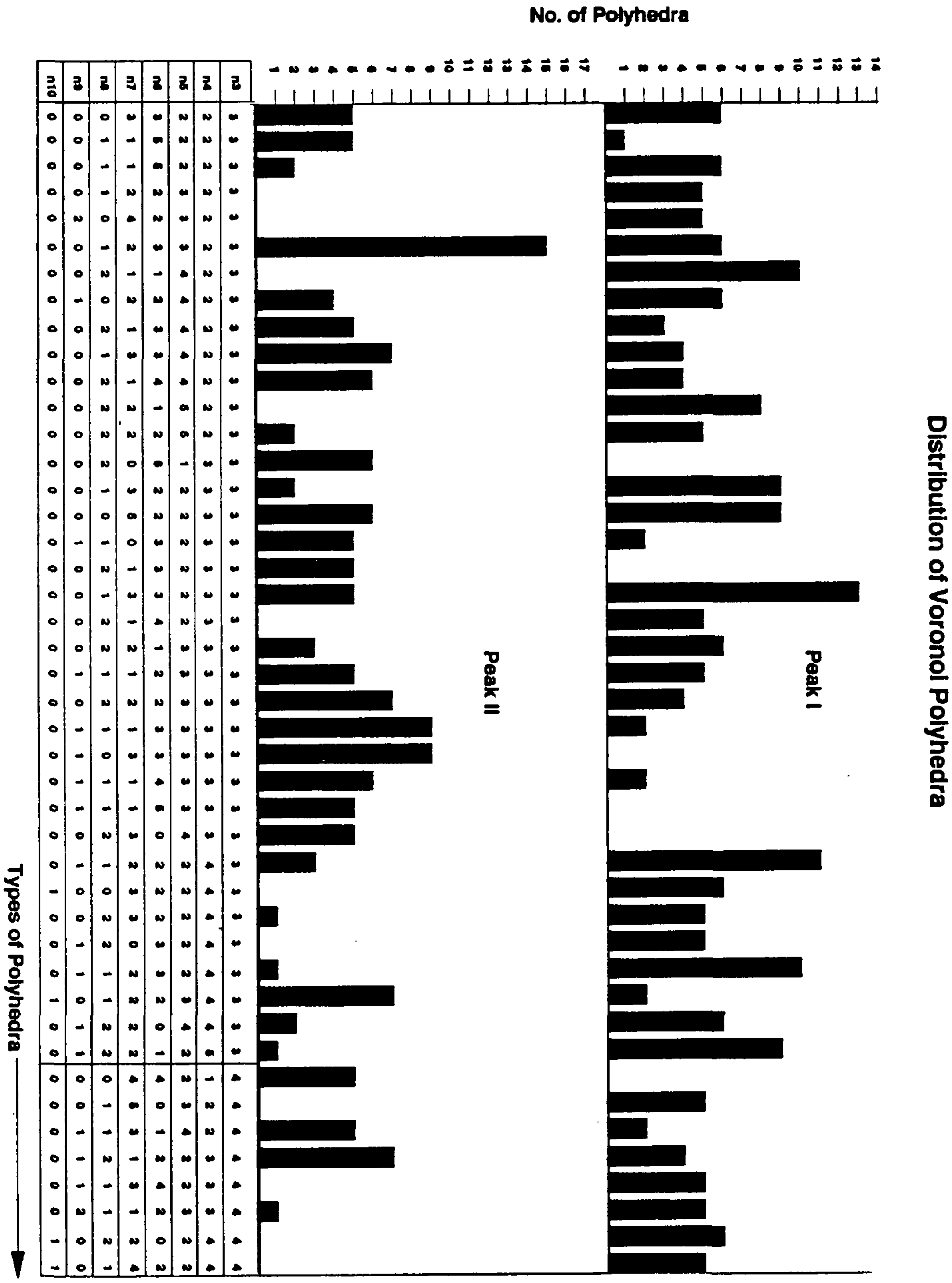

Energy—Volume Distribution in SPC/E Water
F(E,V)
0
5
10
15
20
25
30
35
40
45
50
55
Energy (kJ/molecule)*E20
-1.38E-001
-5.77E-002
-5.88E-003
4.58E-002
9.75E-002
Volume (nm^3)
0.043
0.037
0.032
0.027
0.022

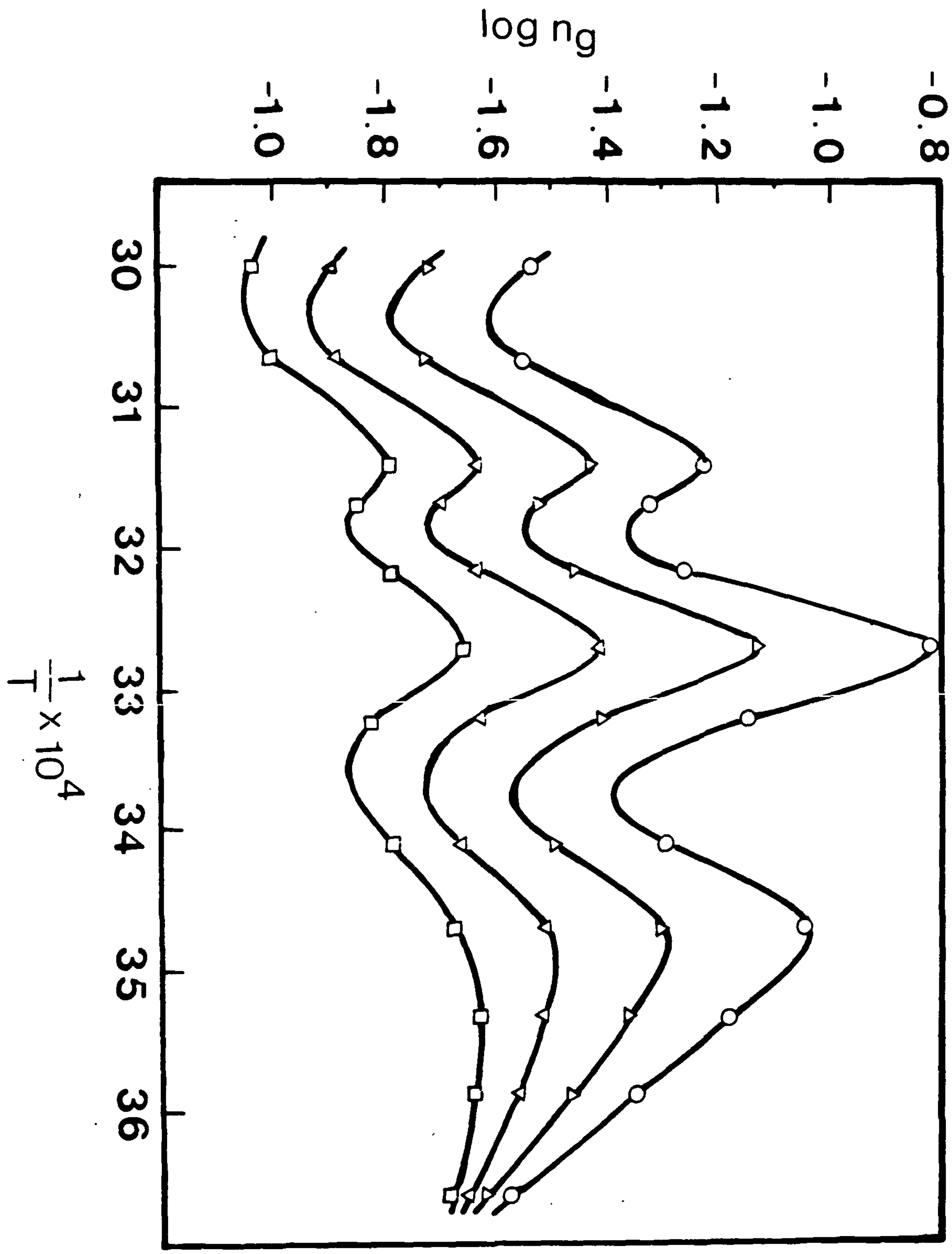


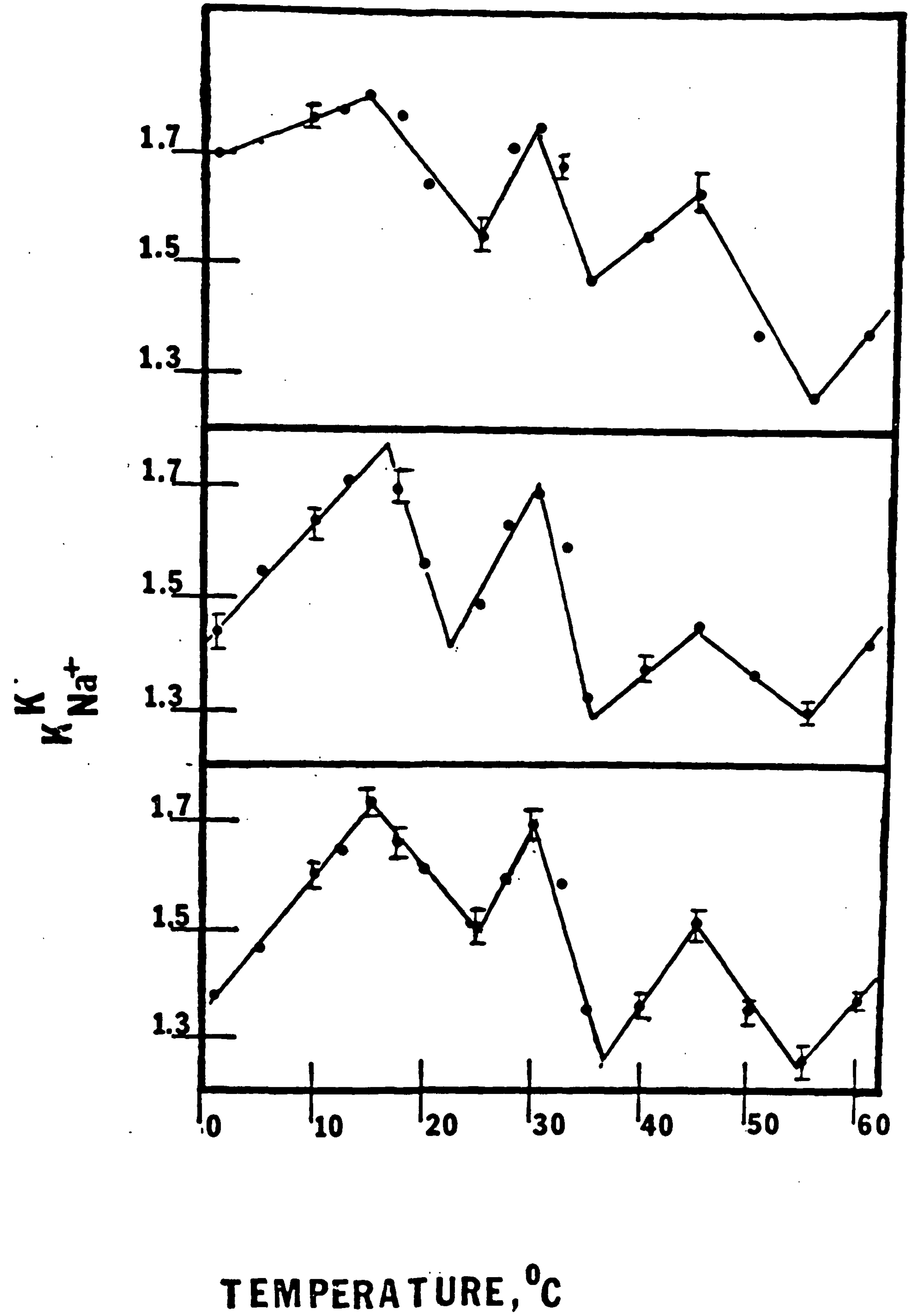
Energy–Volume Distribution in SPC/E Water

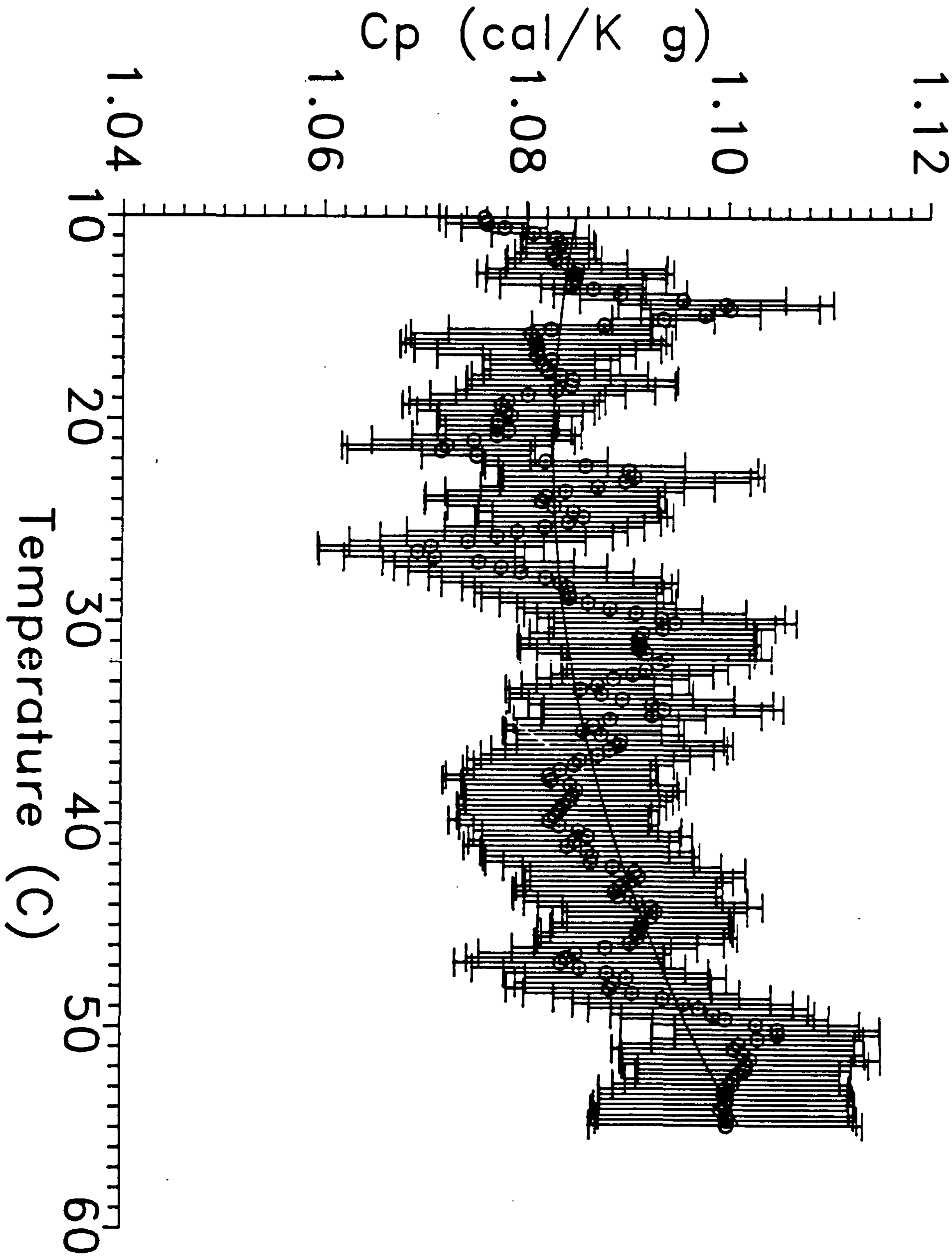

Distribution of Voronoi Polyhedra
No. of Polyhedra
Types of Polyhedra
Peak I
Peak II
n3 n4 n5 n6 n7 n8 n9 n10

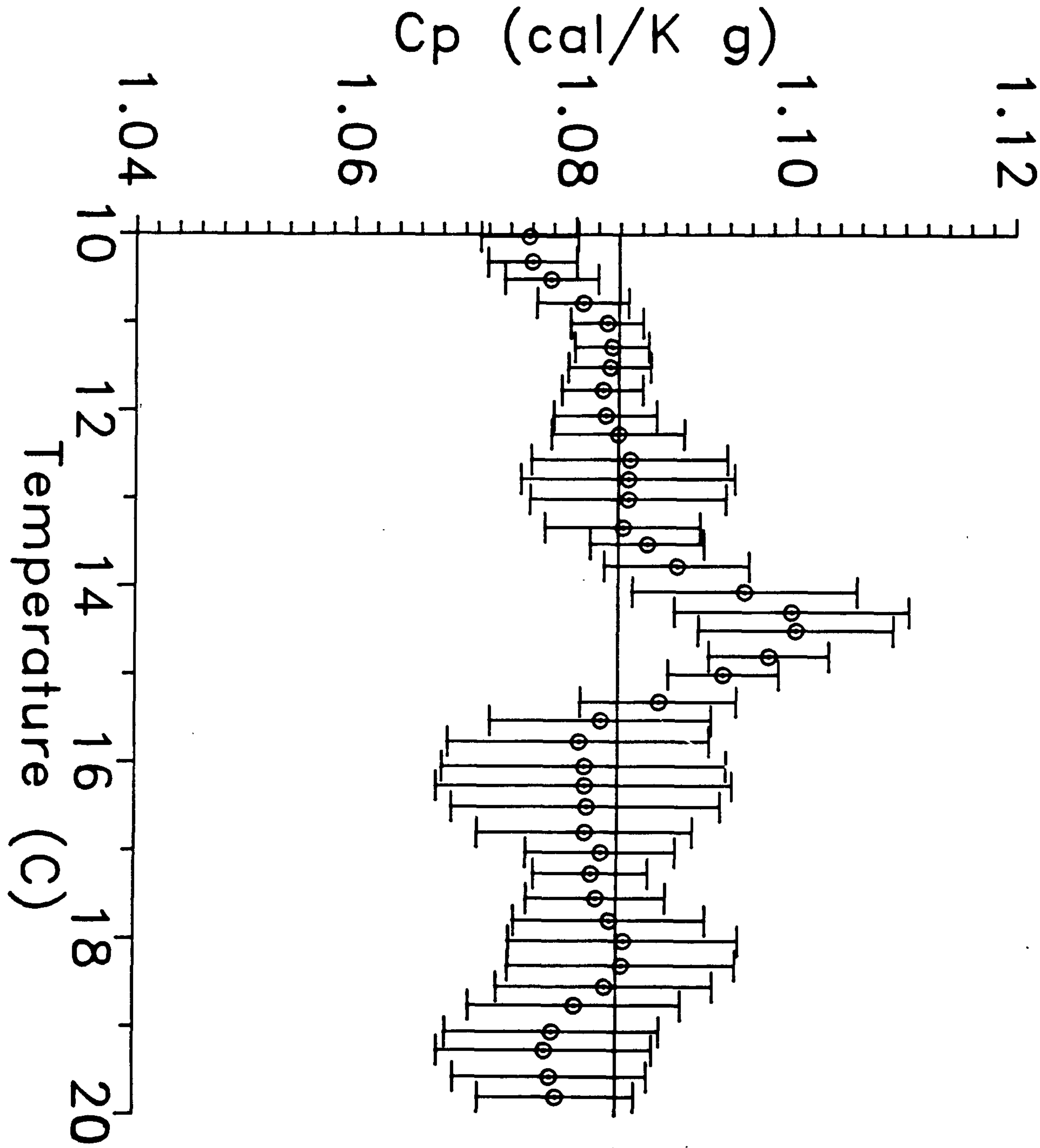

Distribution of Voronoi Polyhedra
No. of Polyhedra
Peak I
Peak II
Types of Polyhedra

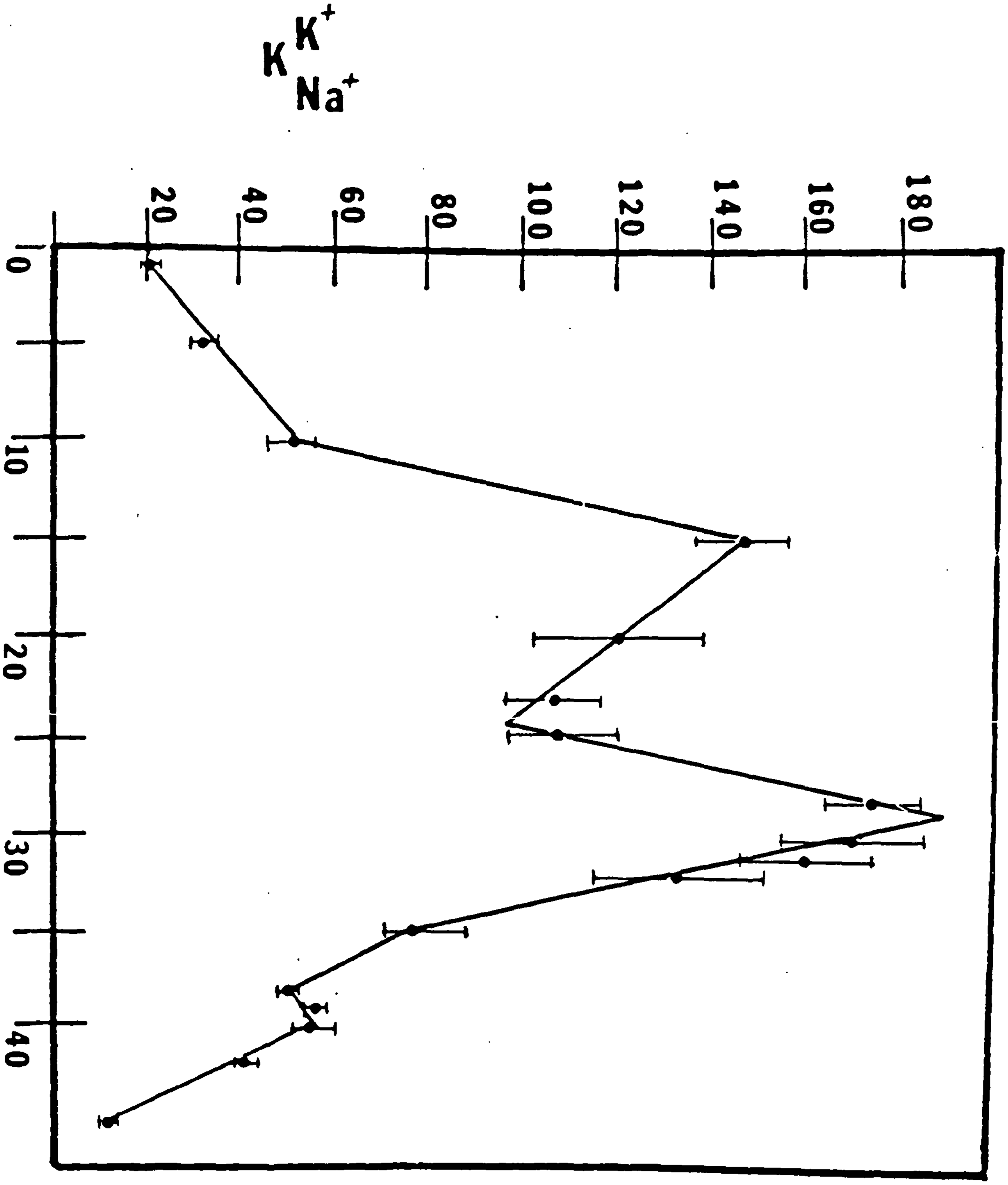

Distribution of Voronoi Polyhedra
No. of Polyhedra
Peak I
Peak II
Types of Polyhedra
n3
n4
n5
n6
n7
n8
n9
n10


log ng
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-1.0
30
31
32
33
34
35
36
1/T × 10^4


1.7
1.5
1.3
1.7
1.5
1.3
1.7
1.5
1.3
0
10
20
30
40
50
60
$K^{K^+}_{Na^+}$
TEMPERATURE, °C


Cp (cal/K g)
1.04
1.06
1.08
1.10
1.12
10
20
30
40
50
60
Temperature (C)


Cp (cal/K g)
1.04
1.06
1.08
1.10
1.12
Temperature (C)
10
12
14
16
18
20


K
K+
Na+
20
40
60
80
100
120
140
160
180
0
10
20
30
40

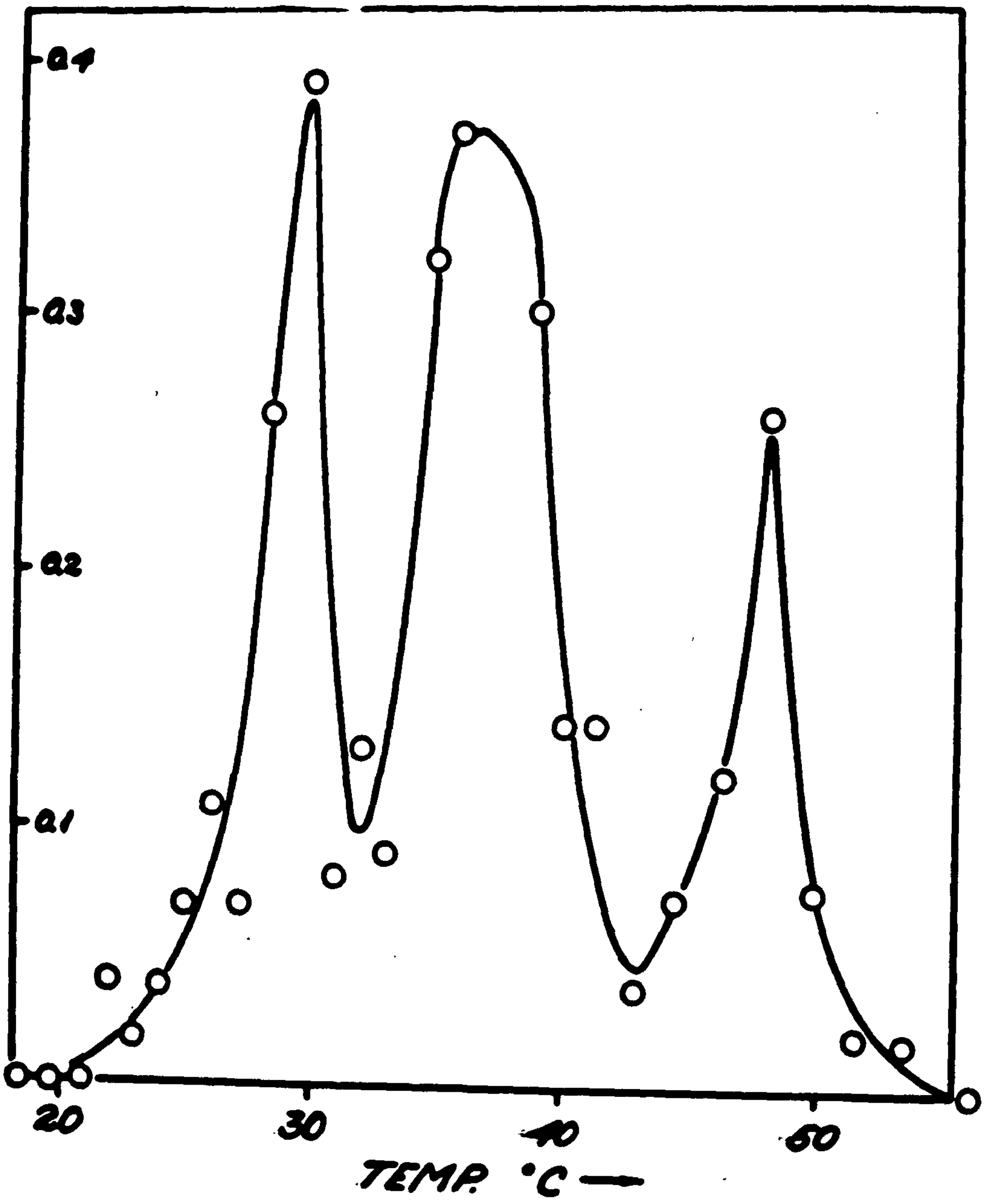


Figure 7. *Growth of Cyanidium caldarium (grown on NH_4^+-containing merium) as a function of temperature. See text for details.*

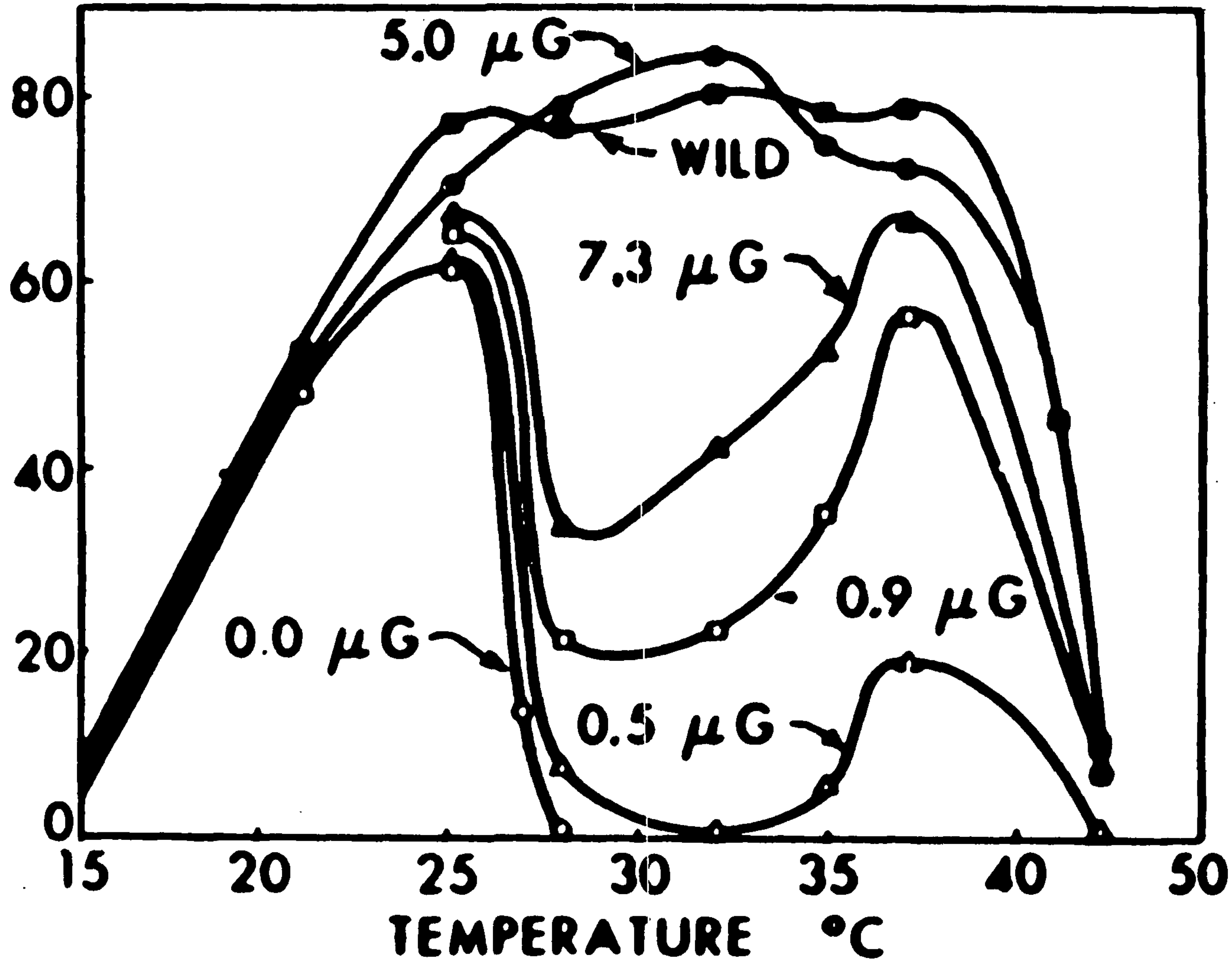


Figure 1. Multiple growth optima for a mold (a mutant of Neurospora crassa*) as a function of temperature with different amounts of riboflavin present* (1)