ORIENTED STRANDBOARD
(OSB) OPTIMIZATION
FP 2.1.1

Alberta Research Council
Industrial Technologies Department
Forest Products Program [1]

1987

This is a joint publication of the Canadian Forestry Service
and the Alberta Forest Service pursuant to the
Canada-Alberta Forest Resource Development Agreement

[1]Edmonton, Alberta

Project No. 2760-27

DISCLAIMER

The study on which this report is based was funded in part under the Canada-Alberta Forest Resource Development Agreement.

***Reprint of an original report previously printed in 1987.**

Catalogue No.: **FO 42-91/29-1988E**
ISBN: **0-662-15971-3**

Additional copies of this publication is available at no charge from:

Forestry Canada
Regional Development
5320 - 122nd Street
T6H 3S5
Telephone: (403) 435 - 7210

or

Forestry, Lands and Wildlife
Forest Industry Development Division
108th Street Building
930, 9942 - 108th Street
Edmonton, Alberta Canada
T5K 2J5
Telephone: (403) 422 - 7011

EXECUTIVE SUMMARY

In the manufacture of composite products there are many factors affecting the ultimate board properties. In most cases, there is a trade-off between quality and price. Once a desired level of quality has been defined, there are many combinations of the production variables to achieve the desired level.

One such approach is PANELMAX, a computer program model, developed to assist industry in making informal management decisions on operating policies in the production of panel products. His "designed for the maximization of variable will profit from existing mills ...", while meeting the desired panel properties.

The purpose of this study was to provide consistant experimental data from a single reliable source where all constants are known and the variables closely controlled. This data is to be used to prove out the PANELMAX program. Two production variables chosen for the study were density and resin content.

Eighty test panels were manufactured at the Alberta Research Council's Panel Development Laboratory using three resin contents and four density levels.

A complete statistical analysis was undertaken on the data resulting from the Forest Products Laboratory testing program. Response variables were measured for various combinations of four nominal resin content levels (1.2%, 1.8%, 2.4%, 3.0%) and four nominal density levels (560, 620, 680, 720 kg/cu.m.). The response variables considered for the statistical analysis included:

1. Dry Modulus of Rupture (MPa)

2. Dry Modulus of Elasticity (MPa)

3. Modulus of Rupture - After 2 Hour Boil (MPa)

4. Internal Bond (MPa)

5. Thickness Swell (%)

6. Linear Expansion (%)

The statistical analysis of the data revealed very strong relationships between MOR (dry and 2 hour boil) and density; between MOE and density; and between internal bond and resin content. Weaker relationships were found between MOR (dry and 2 hour boil) and resin content; between MOE and resin content; and between internal bond and density. The results of the thickness swell and linear expansion tests are much less conclusive, with few strong trends being identified. The data generated by these tests is well suited for inclusion into the PANELMAX model, and is presently being incorporated into the model.

Four areas of work are presently being undertaken on the PANELMAX model:

1. Modify PANELMAX in order to accommodate more than one strength property to be considered in the optimization at any given time.
2. Construct the data matrices for use by the PANELMAX model.
3. Examine and update the profit function used by PANELMAX. New data available to Silvacom Ltd. will enable the construction of a much more realistic profit function subroutine.
4. Test PANELMAX with the new data. Evaluate future research and development needs.

This was the first year of a major study to optimize OSB manufacture and to evaluate PANELMAX in their light. There are many variables still to be evaluated. The work should also be expanded to include the effect on performance properties, since this seems to be the direction in which both Canada and the United States are moving.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

Title Page

LIST OF APPENDICES

Appendix Page

LIST OF FIGURES

Figure Page

LIST OF TABLES

Table Page

1. OBJECTIVES AND GOALS

The following objectives and goals for the year ended March 31, 1987, are as set out in Proposal for Basic 1986/87 Funding of the ARC Forest Products Program to the B.4 Canada/Alberta Forest Resource Development Agreement Committee. Document No. 86-PFP-8, March 10, 1986, and as agreed to by C/A FRDA.

Project #2.1: OPTIMIZATION OF PANEL MANUFACTURING

Objective of the Project:

To produce a model for optimization.

Study #2.1.1: Oriented Strandboard

Objective of this Study:

To define the interaction of process variable in the manufacture of oriented strandboard.

Goals for this Year:

Produce optimization model data for OSB with respect to wafer geometry, wafer alignment, wafer quality, press scheduling, and resin blending.

2. INTRODUCTION

After a preliminary review of available data and literature, resin content and density were identified as the two major factors affecting panel properties in OSB. The study described in this report is the first part of a major study to define the interactions of production variables and board properties in the effort to optimize production.

3. METHODS AND MATERIALS

3.1 Materials and Panel Specifications

In total, 119 panels were made at the Alberta Research Council's Panel Development Laboratory. Specifications were as follows:

Furnish:	- Populus tremuloides (trembling Aspen) - Dried screened face material waferized by Wellwood at Slave Lake, Alberta - 5.9% average OD moisture content (ranged from 5.5% to 6.3%)

Resin:
- Powered phenol formaldehyde (PF)
- Produced by: Reichhold Company
- Tradename: IB-947 (see Appendix I for technical bulletin)

Wax:
- Esso 778 slack wax

The panels were made to the following specifications:

Resin Content:
- Panels with four resin levels were made:
  1) 1.2% of OD furnish weight
  2) 1.8% of OD furnish weight
  3) 2.4% of OD furnish weight
  4) 3.0% of OD furnish weight

Wax Content:
- 1.2% of OD furnish weight

Panel Construction:
- homogeneous

Strand Orientation:
- random

Target Thickness:
- 11.1 mm (7/16 in.)

Target Density:
- Panels of four target density levels were made at each resin level:
  1) 560 kg/m^3 (35.0 lb/ft^3)
  2) 620 kg/m^3 (38.7 lb/ft^3)
  3) 680 kg/m^3 (42.5 lb/ft^3)
  4) 740 kg/m^3 (46.2 lb/ft^3)

Panel Dimension:
- 685 x 1250 mm (27 x 49.25 in.) untrimmed
- 610 x 1220 mm (24 x 48 in.) trimmed

The experimental design is shown in Table 1. Note that although 119 panels were manufactured, only 80 were selected for testing due to the density and thickness tolerance requirements.

Table 1: Experimental Design

		RESIN CONTENT			
		1.2%	1.8%	2.4%	3.0%
DENSITY	560 kg/m^3	5 panels	5 panels	5 panels	5 panels
	620 kg/m^3	5 panels	5 panels	5 panels	5 panels
	680 kg/m^3	5 panels	5 panels	5 panels	5 panels
	740 kg/m^3	5 panels	5 panels	5 panels	5 panels

3.2 Methods of Panel Manufacture

3.2.1 Blending of Materials

Blending of the materials was done in a 2440 mm (8 ft) diameter, 1220 mm (4 ft) deep laboratory drum blender. The rotation of the blender was maintained at approximately 23 rev/min. to provide a cascade of the furnish. The blending cycle was as follows:

i) Melted wax was applied to the furnish through three atomizing spray nozzles at a rate of approximately 180 g/min. A sight glass on the wax pot was used to measure the quantity applied.

ii) A weighed quantity of powder resin was added to the furnish in the drum.

iii) The material was mixed for nine (9) minutes to allow the resin to spread evenly onto the furnish.

The material was mixed in batches of 45 kg green furnish weight.

3.2.2 Forming of the Mat

Each mat of furnish was formed by hand in a 770 x 1320 mm retaining box. The furnish was dispersed in small quantities in order to reduce stacking and bridging of the strands which alter the bulk density. The mat was continually weighed during the forming process to achieve consistent densities from panel to panel.

The mats were transportd in and out of the press on top of a 685 x 1295 mm, 3.2 mm thick steel caul plate. An identical caul plate was placed over the formed mat prior to it being pressed.

3.2.3 Pressing of the Panels

The panels were pressed in a 712 x 1320 mm platen area laboratory hot press. The platens of this 500 ton capacity hydraulic press are heated electrically (maximum 70 kW of power available).

The platen temperature was set at 205 deg. C. Measurement of the coreline temperature was taken for a few panels to ensure that the core was attaining a high enough temperature for the resin to cure. The measurements were taken by a thermocouple positioned approximately at mid-thickness of the panel and 130 mm from the edges of one corner. Coreline temperature measurements were only recorded for low density panels, since the rate of temperature rise increases with increased pressure. A typical profile is shown in Figure 1.

To allow relatively equal cure of all the panels, the total press time, not including placement and removal of the panel, was kept to between 4:50 and 5:30 minutes. 4:50 minutes was enough to cure the resin even at the low panel density of 560 kg/m^3 (see Figure 1).

All panels were pressed to metal stops positioned at the four corners of the platens. The stops equalized the panel thickness at the four corners of the panel, but did not significantly alter the total pressure on the panel. A press schedule (to pressure setpoint) was run from a programmable process controller for each press cycle in order to ensure that very little press load would be taken by the stops. Note that in the pressure cycle ramping rate was the same for all densities and resin contents.

The press schedule consisted of the following four basic load stages:

a) Compression at a high maximum pressure.

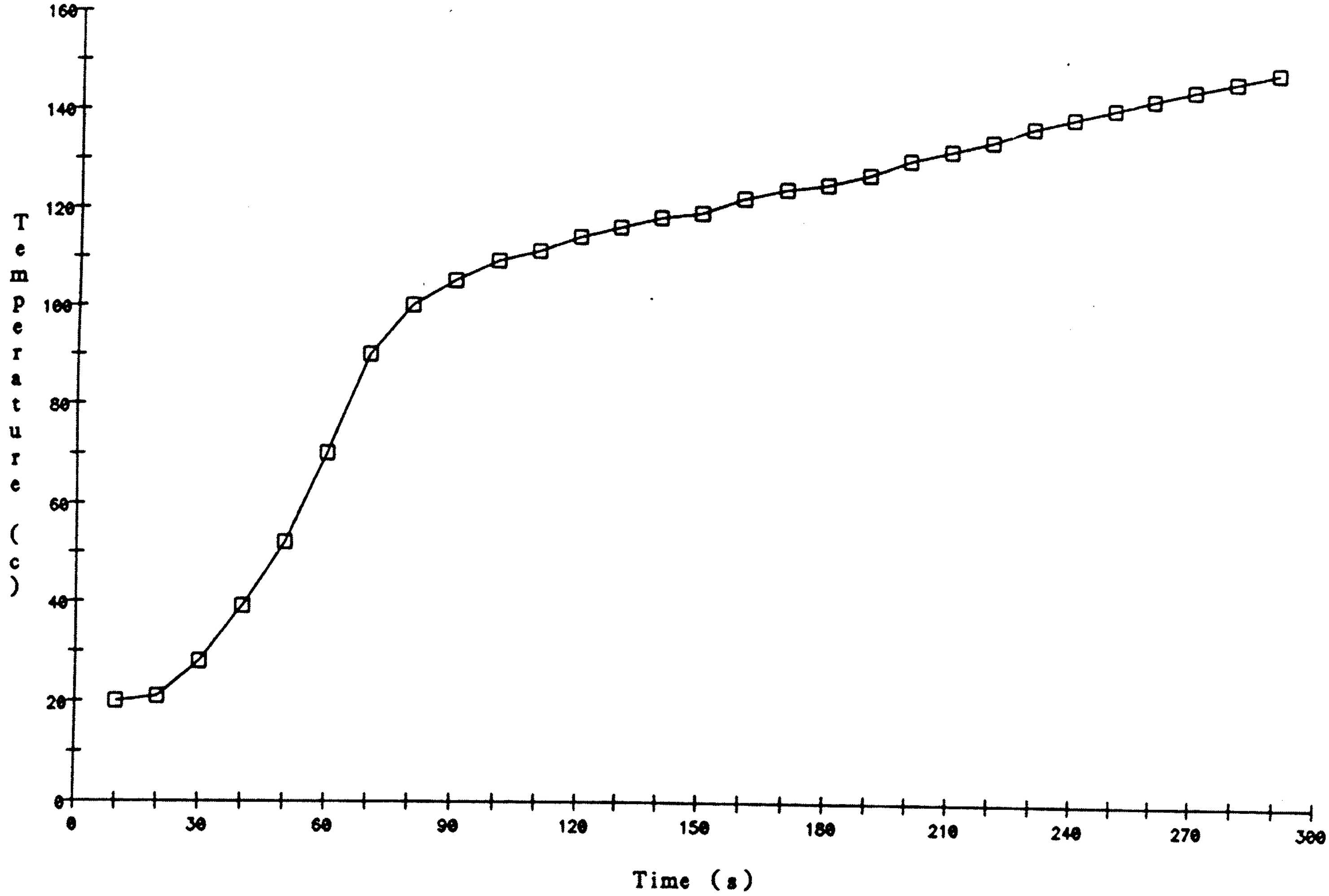
b) Compression at an intermediate pressure to attain the target thickness.

c) Hold at low pressure to maintain constant thickness.

d) Decompression to nearly no press load to allow the steam to be slowly released from the core of the panel.

In addition to the varying target densities, the different resin contents of the panels altered the panel pressing characteristics. As a result, the press cycle for each trail had to be modified to compensate for differences in the rate of compression and the amount of panel spring back.

Figure 1: Typical Coreline Temperature Profile of Panels Having a Density of 560 kg/m^3



Plots of typical press cycles are shown in Appendix II. The press load in these plots was obtained from the oil pressure measurement in the hydraulic cylinder which was previously calibrated to the press load.

The pressure on the panel (assuming no load was taken by the stops) can be calculated by dividing the press load by the panel dimensional area:

$$\text{Panel Pressure [KPa]} = \frac{\text{Press Load [kN]}}{.685\ \text{m} * 1.250\ \text{m}} = 1.17 * \text{Press Load [kN]}$$

The plots of the press load also show the displacement between top and bottom platen measured by an LVDT positioned at one corner of the platens. This distance does not correspond to the actual panel thickness because of the zero offset caused by the thickness of the cauls and a small zero error. This measurement is, however, constant from panel to panel.

Panel thickness measurements with a micrometer and weight were taken after each panel was produced in order that the press cycle could be modified to attain the target thickness and density values.

Enough panels were made to obtain at least five (5) "test" panels at each resin and density level. "Test" panels required that the density be within 10 kg/m^3 (0.6 lb/ft^3) of the target density and the average thickness be within 0.3 mm (0.012 in.) of the target thickness.

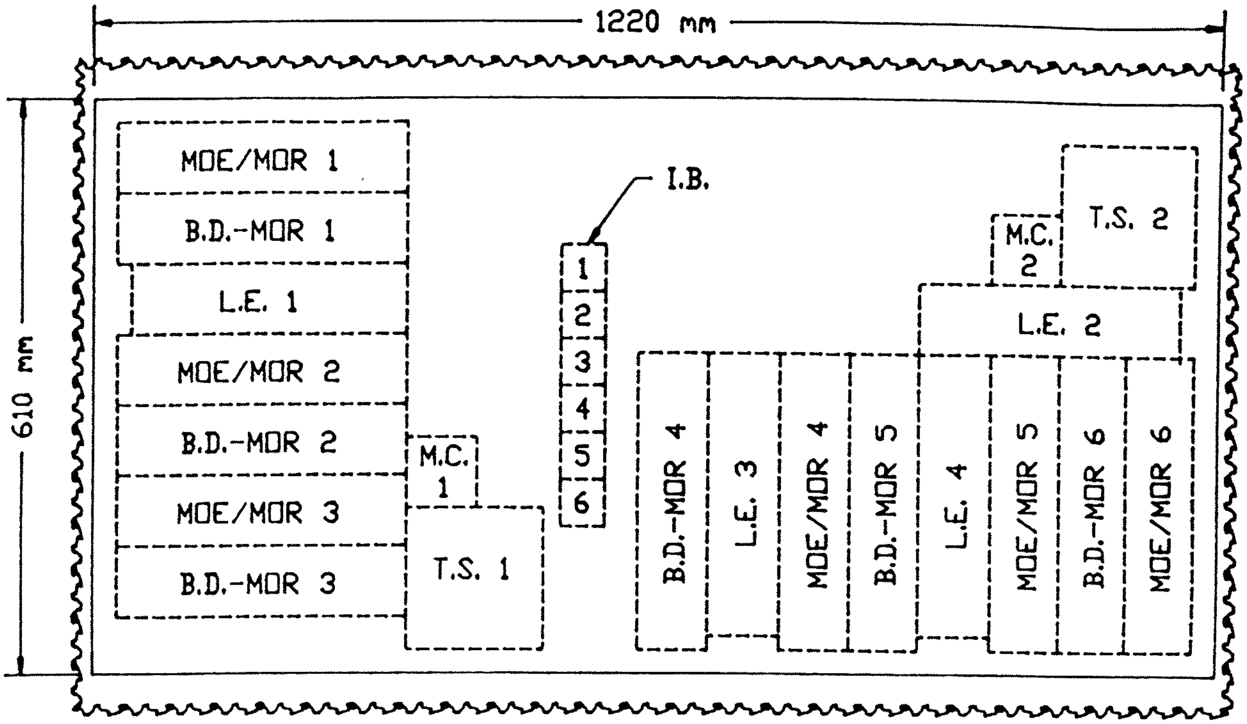
3.3 Methods For Panel Testing Evaluation

From each group of panels respresenting a density and resin content level, five panels were selected for testing. These panels were cut to test specimen size as shown in Figure 2. During cut-up, care was taken to avoid any defects due to forming, pressing, or post pressing damage.

Test methods are summarized in Table 2. All testing followed the requirements of CAN3-0437.1-M "Test Methods for Waferboard and Strandboard" with the exception of moisture content and density. Static bending test pieces were used to determine moisture content and density. All testing not requiring special conditioning was done in the "as received" moisture condition.

Evaluation procedures were as specified by CAN3-0437.0-M for Grade R-1 (waferboard). Although this study is entitled "OSB Optimization", it was considered proper to develop basic treatment interactions on a random oriented test panel. Maintaining consistent orientation on a lab scale would have required a much larger sample size to overcome forming variability. These panels were made at the time that the orienting heads were being commissioned.

Figure 2: <u>Panel Cut-up Pattern for 610 x 1220 mm Panels</u>



Legend	Number	Size	Test
MOE/MOR	6 (1,2,3 para. 4,5,6 perp.)	75 x 315 mm	Modulus of Elasticity and Modulus of Rupture
B.D.-MOR	6 (1,2,3 para. 4,5,6 perp.)	75 x 315 mm	Bond Durability- MOR after 2 h boil
L.E.	4 (1,2 para. 3,4 perp.)	75 x 300 mm	Linear Expansion- oven dry to saturated
I.B.	6	50 x 50 mm	Internal Bond
T.S.	2	150 x 150 mm	Thickness Swell- 24 h soak
M.C.	2	75 x 75 mm	Moisture Content and Density

Table 2: Test Methods for 610 x 1220 mm Panels

Test	Standard	Clause	Tests/ Panel	Total Tests/ Group
Modulus of Rupture (MOR)	CAN3-0437.1-M	5.7		
- parallel			3	15
- perpendicular			3	15
Modulus of Elasticity (MOE)	CAN3-0437.1-M	5.7		
- parallel			3	15
- perpendicular			3	15
Internal Bond	CAN3-0437.1-M	5.8	6	30
Bond Durability - MOR after 2 h boil	CAN3-0437.1-M	5.9		
- parallel			3	15
- perpendicular			3	15
Thickness Swell - 24 h soak	CAN3-0437.1-M	5.11	2	10
Linear Expansion - oven dry to saturated	CAN3-0437.1-M	5.12		
- parallel			2	10
- perpendicular			2	10
Moisture Content	ASTM D 1037	126 & 127	2	10
Density	ASTM D 1037 and CAN3-0437.1-M	126 & 127 5.2, 5.3 and 5.6	2	10

4. PANELMAX - THE PANELBOARD PRODUCTION OPTIMIZATION MODEL

4.1 Introduction

PANELMAX is a panelboard production optimization model developed for the Alberta Research Council in 1983 (Grabowski et. al, 1986; Grabowski 1982). Consisting of a package of computer programs, PANELMAX is designed for the maximization of variable mill profits from existing panelboard mills while meeting minimum panel strength requirements. PANELMAX relates the cost of inputs, the price of the finished product, and the desired strength of the panel in order to calculate the optimal levels at which to hold the controllable process variables.

PANELMAX can be a robust management tool (not a management replacement), assisting managers when making decisions about the operating policy of their panelboard mills. Sensitivity analyses can be performed which will test the effects on profitability and panel quality resulting from changes in the proces variables. PANELMAX can also be used by researchers to perform sensitivity analyses on mill operating policy and thereby determine optimal expenditures for research and development programs. Researchers can determine which process variable are most likely to impact the economic performance of panelboard mills, and can set future research and development programs, including investigations of the process variables, accordingly. In this way, priorities for future research are set based on the likely economic significance of the research results.

4.2 The Mathematical Model

The following assumptions have been made for the 1983 version of PANELMAX:

1. The overall goal for the panelboard mill is to maximize profit. In particular, for PANELMAX, the profit goal is defined as the maximization of variable profit/8-hour shift. Fixed costs are ignored because they do not affect the optimal operating policy required to maximize profit.

2. The mill must meet, or exceed, a single minimum level of strength for its panel product. In other words, there is currently no option for the production of a variety of panel grades which can then be marketed. The 1983 version of PANELMAX uses internal bond as the single strength property.

3. All of the panelboard produced can be sold at a specified price provided to the program by the user. The 1983 version of PANELMAX ignores market relationships.

4. The current mill equipment is considered "fixed". In other words, questions of mill design and re-design are not considered in PANELMAX.

The overall objective for PANELMAX is the selection of the "best" operating policy for the panelboard mill as to maximize variable mill profit while meeting or exceeding a minimum requirement for panel strength. Operating policy is defined by a set of values for controllable production process variables such as resin content, nominal panel density, etc. Thus, the objective of PANELMAX is to select the optimal values for the operating policy variables under consideration so that variable mill profit is maximized and panel strength equals, or exceeds, a minimum desired value.

In order to solve the constrained maximization problem, two non-classical mathematical techniques were selected. Everett's method of Lagrange multipliers, and the Hooke-Jeeves direct search algorithm. The primary advantage of this combination of mathematical techniques is the ability to use either analytical functions or discrete data to represent profit and panel strength relationships. Restricting assumptions, such as linearity or differentiability, are no required with this robust combination of techniques. This means that the program user does not have to develop analytical functions relating panel strength to the operating policy variables. Instead, test data can be used directly by PANELMAX. Even an "educated guess" about these panel strength relationships is better than nothing. Management must currently make operating policy decisions based on existing information. PANELMAX can help by providing an organized approach for analysing the optimization problem and exploring various management options.

4.3 Fitting the Data to the Model

The 1983 version of PANELMAX used data presented in publically available technical literature. Because the data resulted from a number of researchers and numerous different laboratories, consistency and applicability of results was poor. The initial development of a database by the Alberta Research Council is a significant step towards making PANELMAX usable everyday by Alberta's panel industry. Continued development of this database will greatly enhance the model, providing consistent, high quality inputs to the computer program. Through sensitivity analyses, PANELMAX will feed informaiton back to the researchers at Alberta Research Council, indicating the industrial (economic) significance of the different process variables thus providing guidance regarding which process variables warrant further attention in future testing programs.

The data generated by the current project consists of measurements for a number of parameters as a result of different combinations of two controllable process variables. Four levels of density (560, 620, 680, and 720 kg/cu.m.) and four levels of resine (1.2, 1.8, 2.4, and 3.0 %) produced a total of sixteen combinations for each of six parameters measured (dry MOR, dry MOE, 2 hour boil MOR, Internal Bond, Thickness Swell, Linear Expansion). As is evident from the graphs presented in Section 5, the different performance properties respond quite differently to variation in density and resin content. Furthermore, the relationships are rarely uniform, and would be very difficult to fit using analytical functions. Fortunately, PANELMAX will accept these data in discrete, data table formats.

Currently, the work of fitting the new data set to PANELMAX is still underway. When this is complete, a separate report will be submitted. In summary, however, the following work is presently ongoing:

1. Modify PANELMAX in order to accommodate more than one strength property to be considered in the optimization at any given time.

2. Construct the data matrices for use by PANELMAX.

3. Examine and update the profit function used by PANELMAX. New data available to Silvacom Ltd. will enable the construction of a much more realistic profit function subroutine.

4. Test PANELMAX with the new data. Evaluate future research and development needs.

5. RESULTS AND DISCUSSIONS

5.1 Results and Discussion of Manufacture

Pressing variables have been discussed previously. In the manufacture of these panels, every effort was taken to have resin content and density the only production variables. The pressure cycle ramping speed remained constant, with adjustments being made to maximum pressure, and thickness at first pressure reduction to give the desired final panel thickness and density. The press cycles were entered on the microprocessor that controls the hydraulic hot press to ensure repeatability between panels.

5.2 Test Results - Statistical Analysis

A complete statistical analysis was undertaken on the data resulting from the Forest Products Laboratory testing program. Response variables were measured for various combinations of four nominal resin content levels (1.2%, 1.8%, 2.4%, 3.0%) and four nominal density levels (560, 620, 720 kg/cu.m.). The response variables considered for the statistical analysis are:

1. Dry Modulus of Rupture (M.Pa.)
2. Dry Modulus of Elasticity (M.Pa.)
3. Modulus of Rupture - After 2 Hour Boil (M.Pa.)
4. Internal Bond (M.Pa.)
5. Thickness Swell (%)
6. Linear Expansion (%)

The number of replications varied among the response variables. The statistical analysis was conducted using SPSS. Data summaries are presented in Appendix III. Appendix IV contains complete listings of all analyses.

The results of the analysis of variance have been reduced to a simple-to-read table for each response variable. These tables are presented together with a brief discussion, and accompanying graphs.

Notes on Reading the Tables

The following Tables (3 through 8) contain data for each response variable. Each table is broken into two parts. The top half presents a breakdown of data by density class (all resin classes averaged together). The bottom half presents a breakdown of data by resin class (all density classes averaged together). In this way the reader can identify the impact of each treatment independent of the effects of the other treatment.

Presented in the Tables are averages for the response variable by treatment class, as well as an identification of homogenous subsets existing in the data set. The homogeneous subsets were identified through the use of a one-way analysis of variance. Classes which do not have a commom letter have means (averages) that are significantly different from each other at the 95% confidence level. Thus, Table 3 shows that each density class is significantly different from every other density class when dry MOR is measured (top half of Table 3). The differences between resin classes are less pronounced. Table 3 (bottom half) shows that Class 1 (resin content 1.2%) is significantly different from all other classes. Class 2 (1.8%) is significantly different from Class 1 and Class 4. Class 3 (2.4%) is significantly different from Class 1. Class 4 (3.0% is significantly different from Class 1 and Class 2. Visual examinations of the means, as well as the graphs in Figure 3 and 4, confirm these homogenous subsets. Clearly, Figure 4 shows a distinct family of curves, one for each density level. While there is a trending upwards for resin content, it is not as clear a trend as for density. The family of curves in Figure 3 are not as clearly separated, further illustrating the weaker relationship between MOR and resin content.

5.2.1 Dry MOR

As was discussed in the previous example, Dry MOR exhibits a very strong relationship to density, and a somewhat weaker relationship to resin content.

Table 3: Dry MOR (M.Pa.)

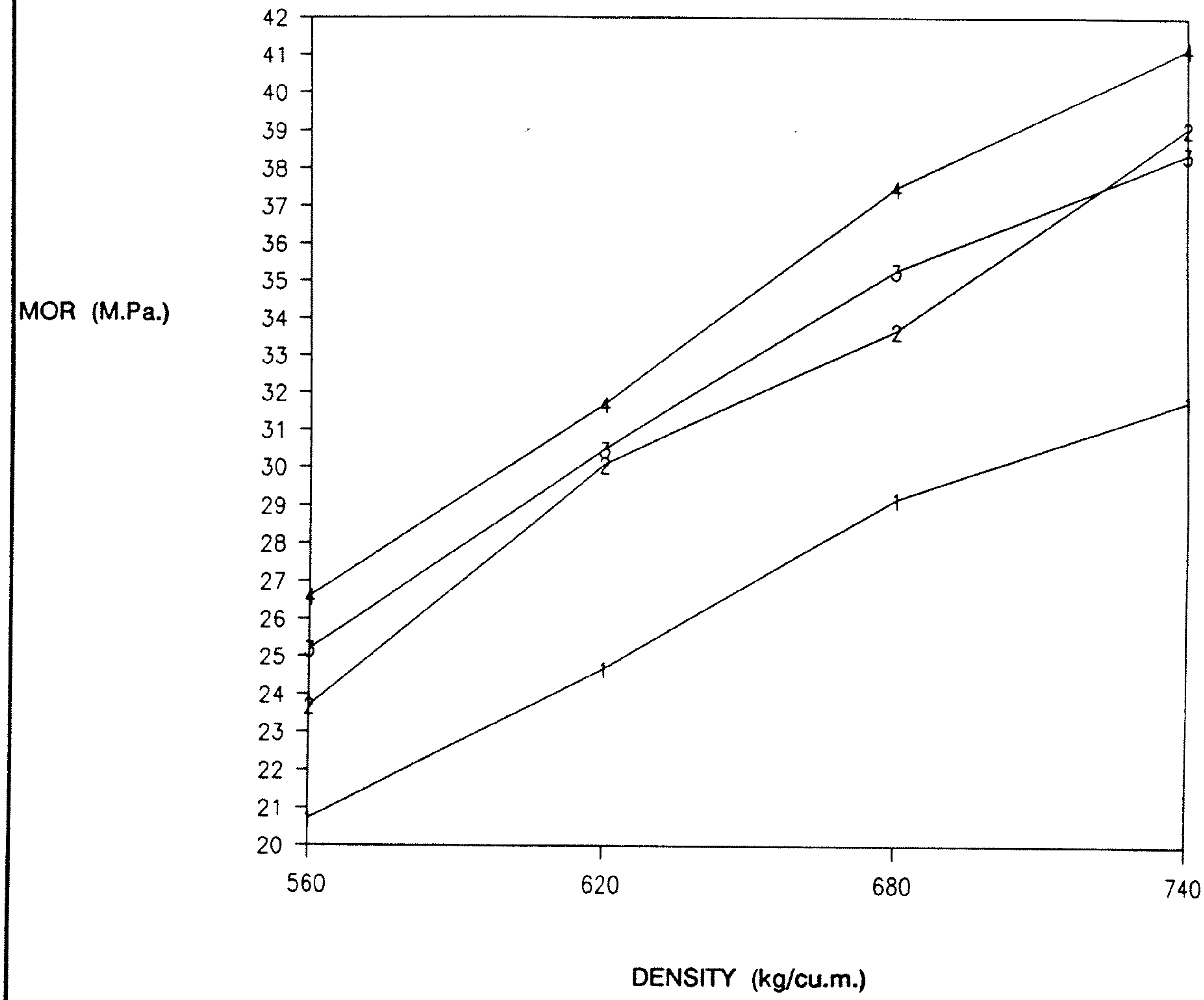
DENSITY CLASS (kg/cu.m.)	AVERAGE DRY MOR (M.Pa.)	HOMOGENOUS SUBSETS
560	24.0417	a
620	29.2433	b
680	33.9100	c
720	37.6208	d

RESIN CLASS (%)	AVERAGE DRY MOR (M.Pa.)	HOMOGENOUS SUBSETS
1.2	26.6025	a
1.8	31.6375	b
2.4	32.3342	b c
3.0	34.2417	c

Details for raw data on which table is based are in Appendix III. For statistical evaluation of same, see Appendix IV.

FIGURE 3. DRY MOR VS. DENSITY AND RESIN CONTENT

EFFECTS OF RESIN CONTENT SHOWN BY FAMILY OF CURVES



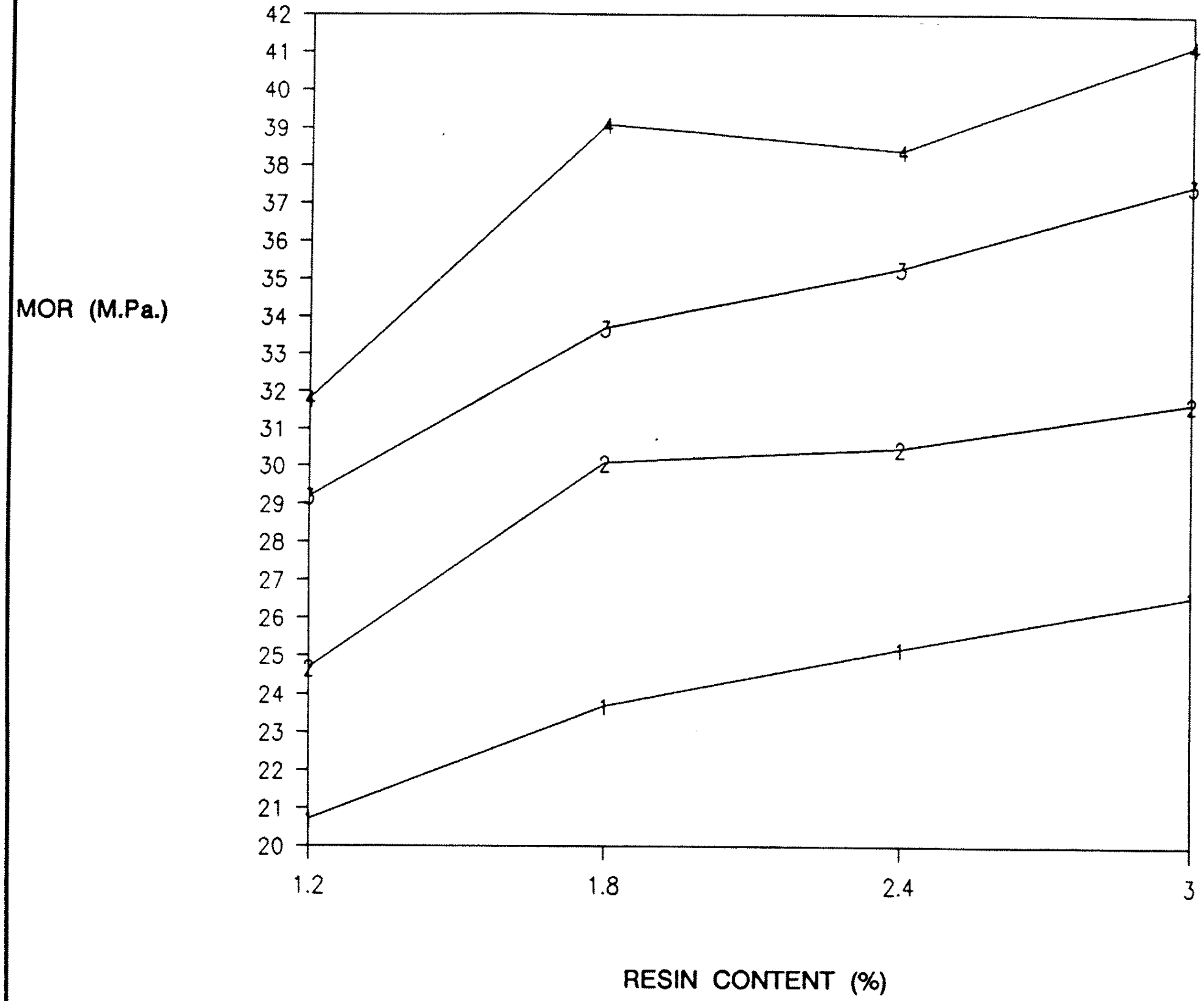
PARALLEL AND PERPENDICULAR AVERAGED

RESIN CONTENT CODES:

1 - 1.2%
2 - 1.8%
3 - 2.4%
4 - 3.0%

FIGURE 4. DRY MOR VS. RESIN CONTENT AND DENSITY

EFFECTS OF DENSITY SHOWN BY FAMILY OF CURVES



PARALLEL AND PERPENDICULAR AVERAGED

DENSITY CODES:

1 - 560 (kg/cu.m.)
2 - 620 (kg/cu.m.)
3 - 680 (kg/cu.m.)
4 - 740 (kg/cu.m.)

5.2.2 Dry MOE

Dry MOE exhibits much the same trends as Dry MOR. Very strong trends are evident between MOE and density class (see Table 4 and Figure 6). The mean MOE at each density level is significantly different from the mean MOE at every other density level. A less pronounced relationship is evident among the resin classes. Examination of the homogenous subsets (see Table 4 and Figure 5) shows a weaker relationship, with unclear trends.

Table 4: Dry MOE (M.Pa.)

DENSITY CLASS (kg/cu.m.)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
560	4093	a
620	4794	b
680	5284	c
720	5700	d

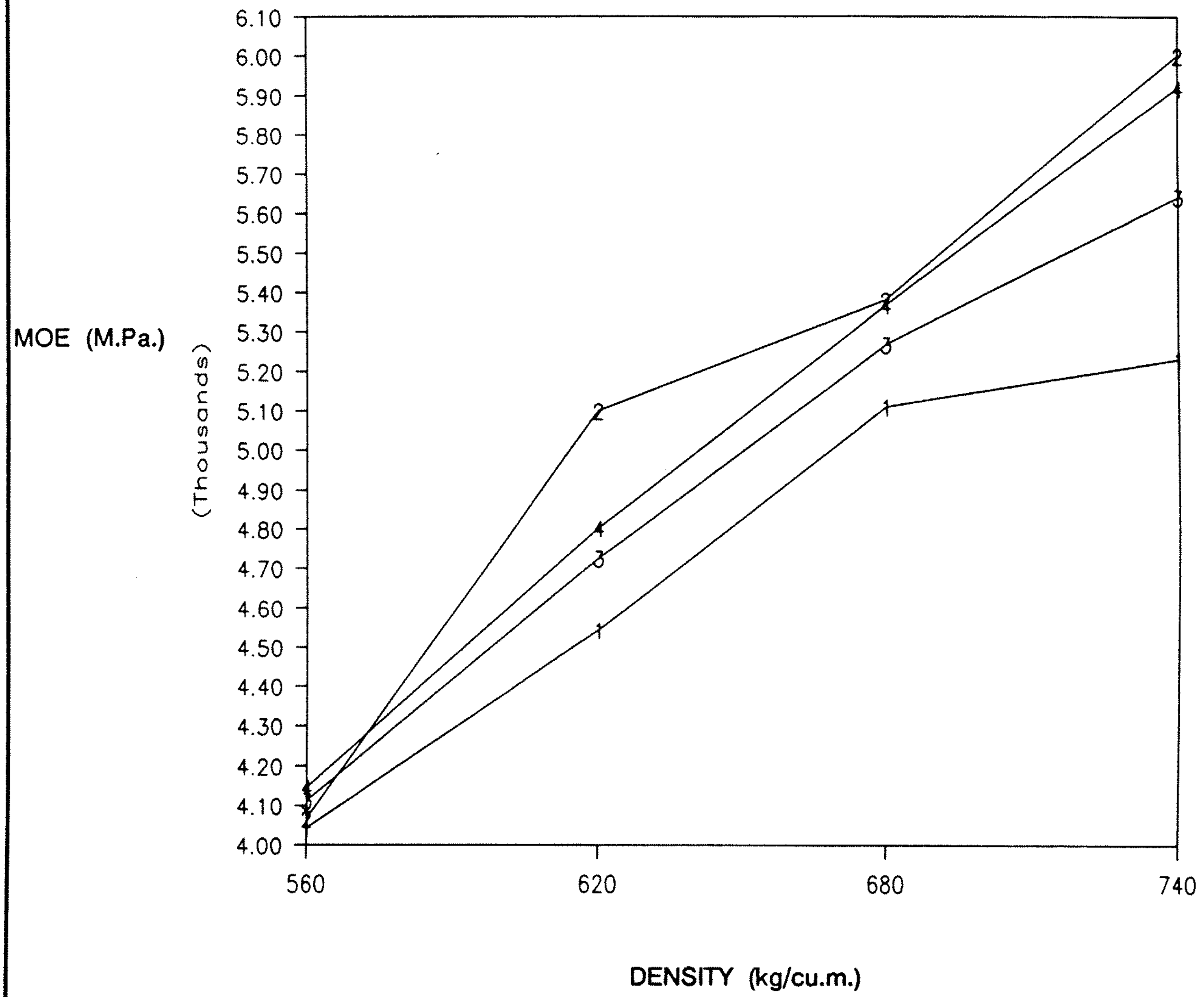
RESIN CLASS (%)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
1.2	4733	a
1.8	5139	b
2.4	4938	a b
3.0	5060	b

Details for raw data on which table is based are in Appendix III.

For statistical evaluation of same see Appendix IV.

FIGURE 5. DRY MOE VS. DENSITY AND RESIN CONTENT

EFFECTS OF RESIN CONTENT SHOWN BY FAMILY OF CURVES



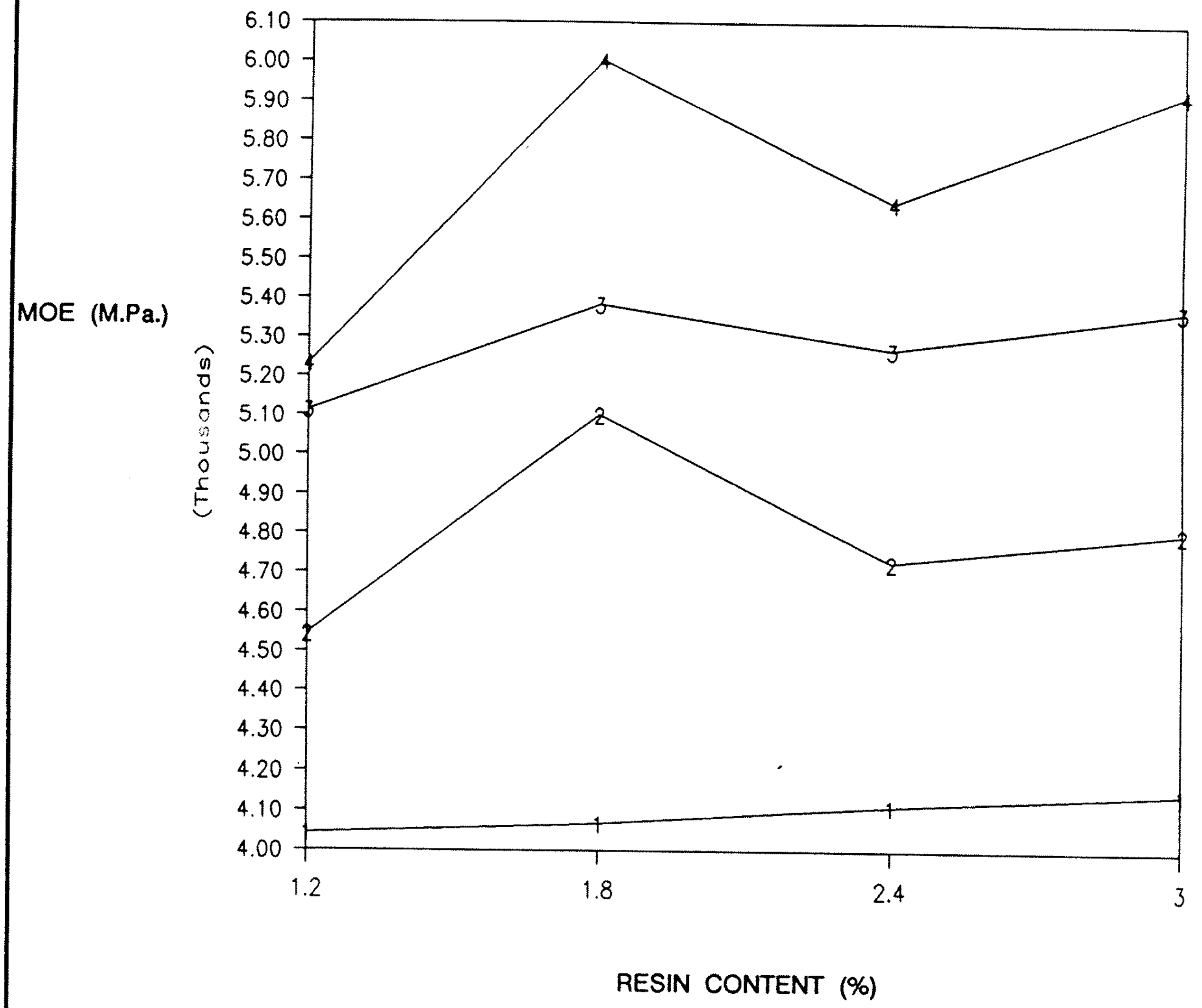
PARALLEL AND PERPENDICULAR AVERAGED

RESIN CONTENT CODES:

1 - 1.2%
2 - 1.8%
3 - 2.4%
4 - 3.0%

FIGURE 6. DRY MOE VS. RESIN CONTENT AND DENSITY

EFFECTS OF DENSITY SHOWN BY FAMILY OF CURVES



PARALLEL AND PERPENDICULAR AVERAGED

DENSITY CODES:

1 - 560 (kg/cu.m.)
2 - 620 (kg/cu.m.)
3 - 680 (kg/cu.m.)
4 - 740 (kg/cu.m.)

5.2.3 MOR - 2 Hour Boil

Like dry MOR and dry MOE, the two hour boil MOR shows clear and definite trends with density class, and much less pronouced trends with resin class. Table 5 and Figures 7 and 8 illustrate these trends.

Table 5: MOR - 2 Hour Boil (M.Pa.)

DENSITY CLASS (kg/cu.m.)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
560	13.1858	a
620	16.5233	b
680	19.1508	c
720	20.7067	d

RESIN CLASS (%)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
1.2	14.3842	a
1.8	17.9717	b
2.4	17.8375	b
3.0	19.3733	c

Details for raw data on which table is based are in Appendix III.
For statistical evaluation of same see Appendix IV.

FIGURE 7. 2 HOUR BOIL MOR VS. DENSITY AND RESIN CONTENT

EFFECTS OF RESIN CONTENT SHOWN BY FAMILY OF CURVES

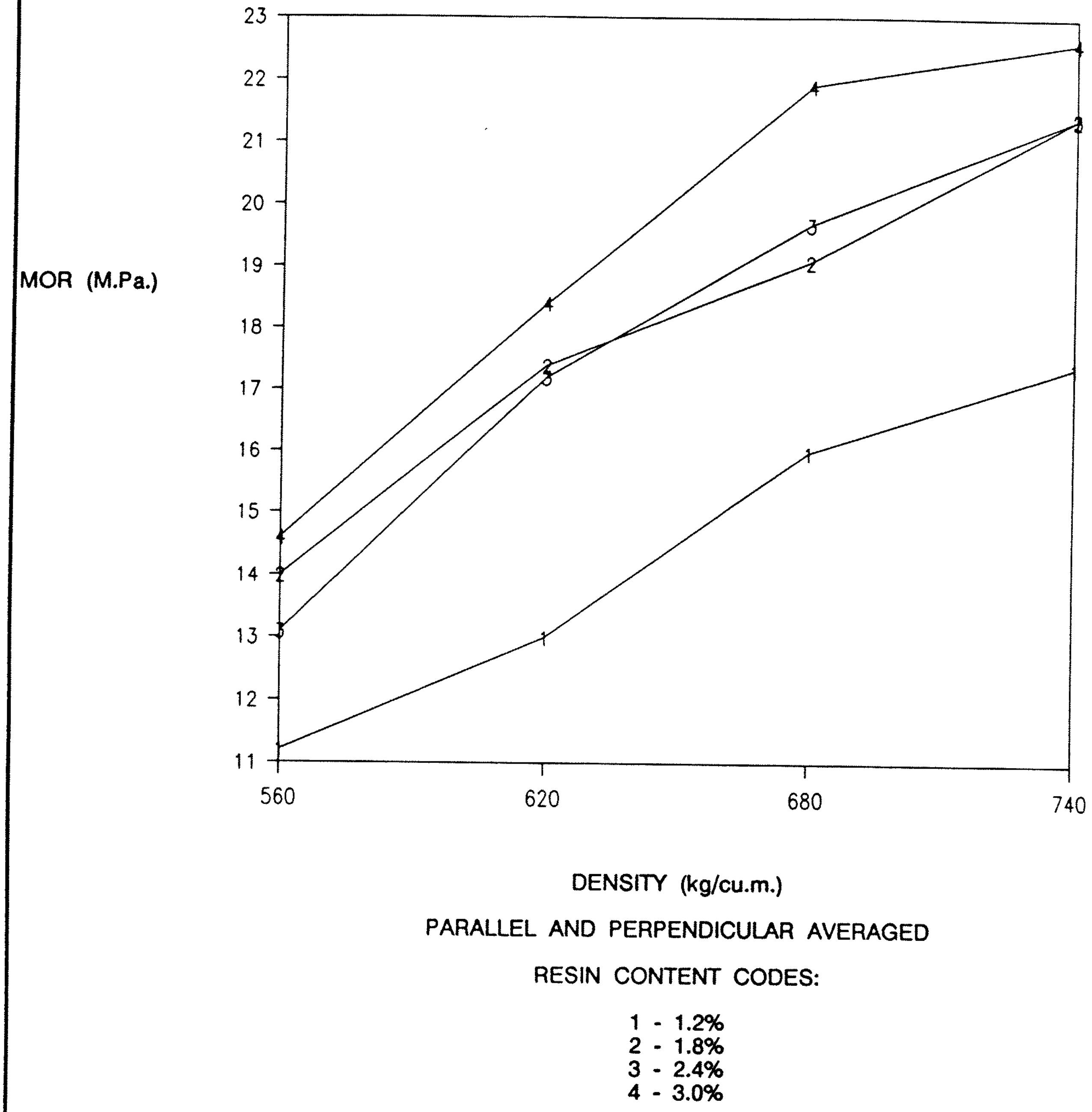
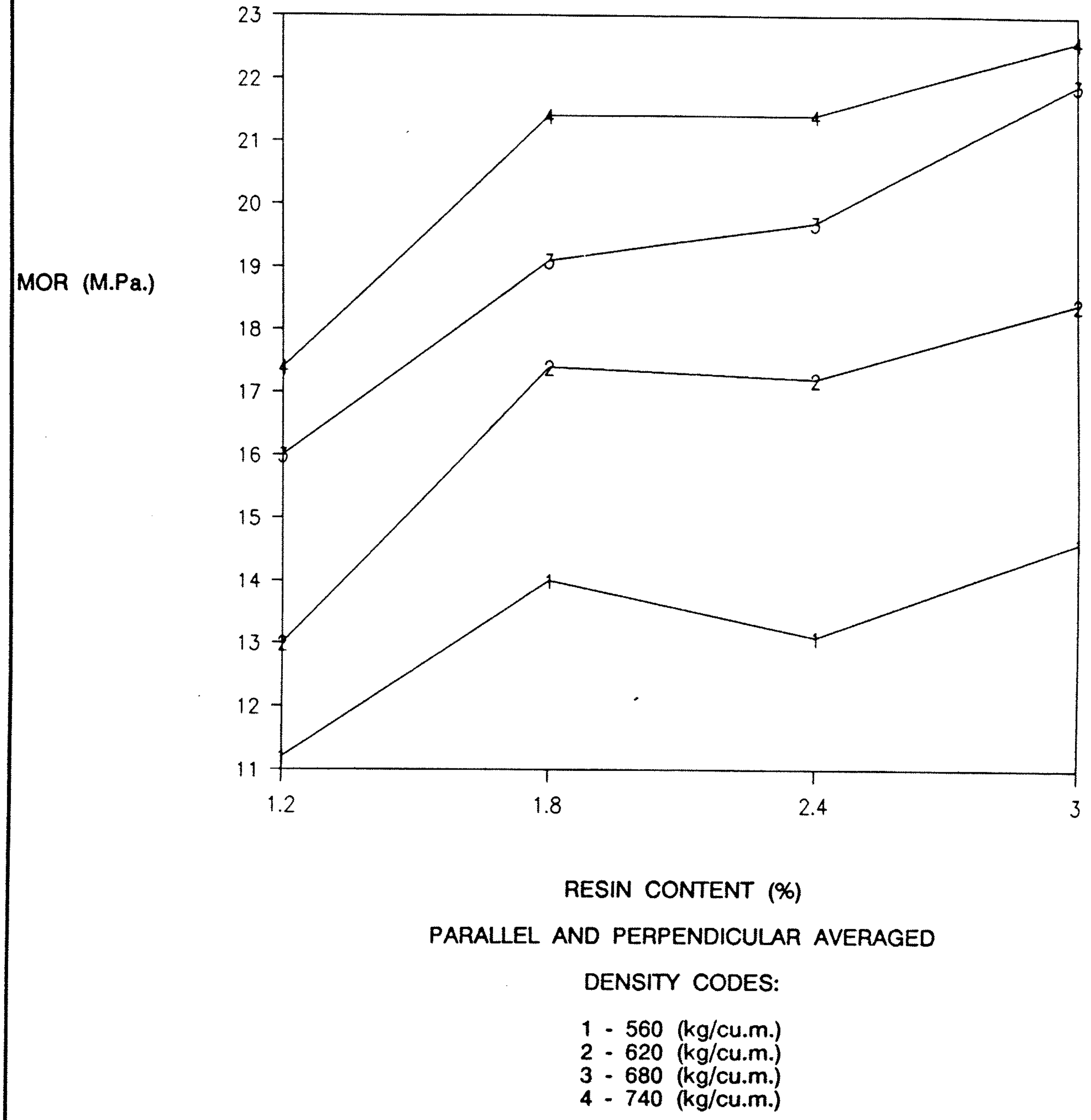


FIGURE 8. 2 HOUR BOIL MOR VS. RESIN CONTENT AND DENSITY

EFFECTS OF DENSITY SHOWN BY FAMILY OF CURVES



5.2.4 Internal Bond

Internal Bond (IB), unlike MOR and MOE, shows a clear trend with resin class and a much less pronouced trend with density class (see Figure 9 and 10, Table 6).

Table 6: Internal Bond (M.Pa.)

DENSITY CLASS (kg/cu.m.)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
560	.4745	a
620	.5397	b
680	.5550	b
720	.5619	b

RESIN CLASS (%)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
1.2	.3833	a
1.8	.4865	b
2.4	.6094	c
3.0	.6520	d

Details for raw data on which table is based are in Appendix III. For statistical evaluation of same see Appendix IV.

FIGURE 9. INTERNAL BOND VS. DENSITY AND RESIN CONTENT

EFFECTS OF RESIN CONTENT SHOWN BY FAMILY OF CURVES

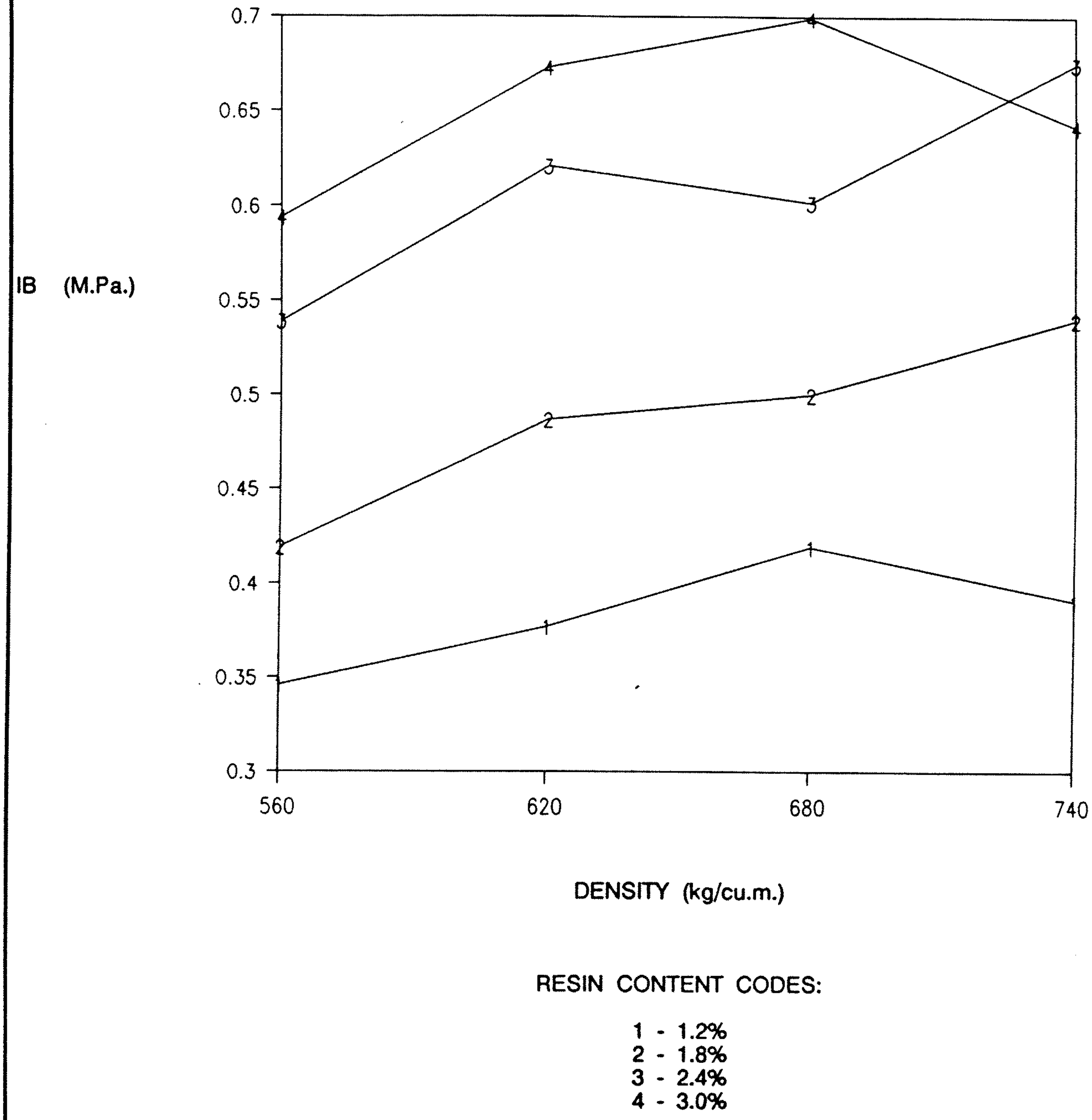
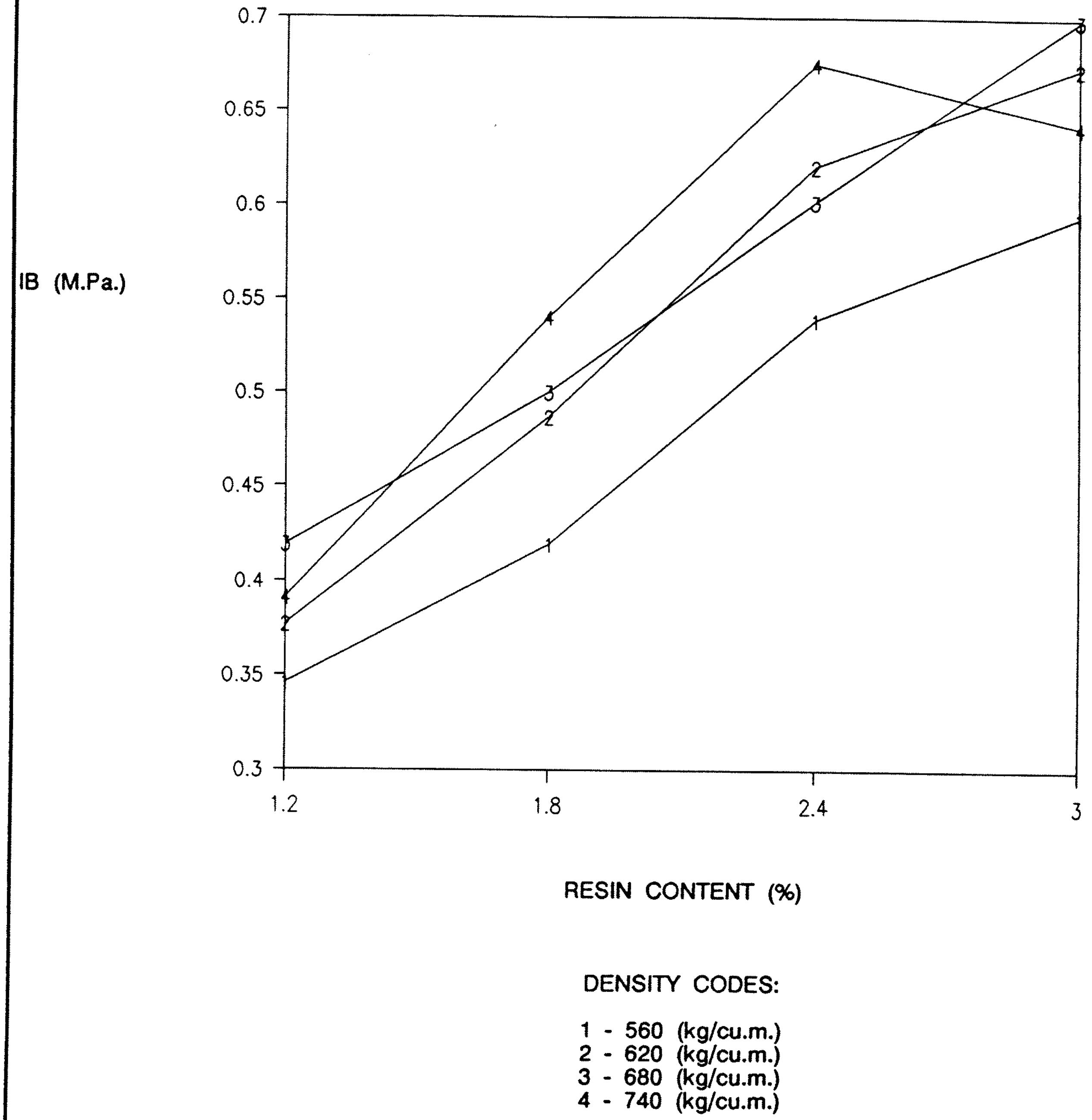


FIGURE 10. INTERNAL BOND VS. RESIN CONTENT AND DENSITY

EFFECTS OF DENSITY SHOWN BY FAMILY OF CURVES



5.2.5 Thickness Swell

Thickness Swell shows a clear trend with density class, and virtually no trend with resin class (Figure 11 and 12, Table 7).

Table 7: Thickness Swell (%)

DENSITY CLASS (kg/cu.m.)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
560	20.8374	a
620	18.6311	b
680	17.1539	c
720	14.4061	d

RESIN CLASS (%)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
1.2	20.0995	b
1.8	17.0016	a
2.4	17.3865	a
3.0	16.5409	a

Details for raw data on which table is based are in Appendix III. For statistical evaluation of same see Appendix IV.

FIGURE 11. THICKNESS SWELL VS. DENSITY AND RESIN CONTENT

EFFECTS OF RESIN CONTENT SHOWN BY FAMILY OF CURVES

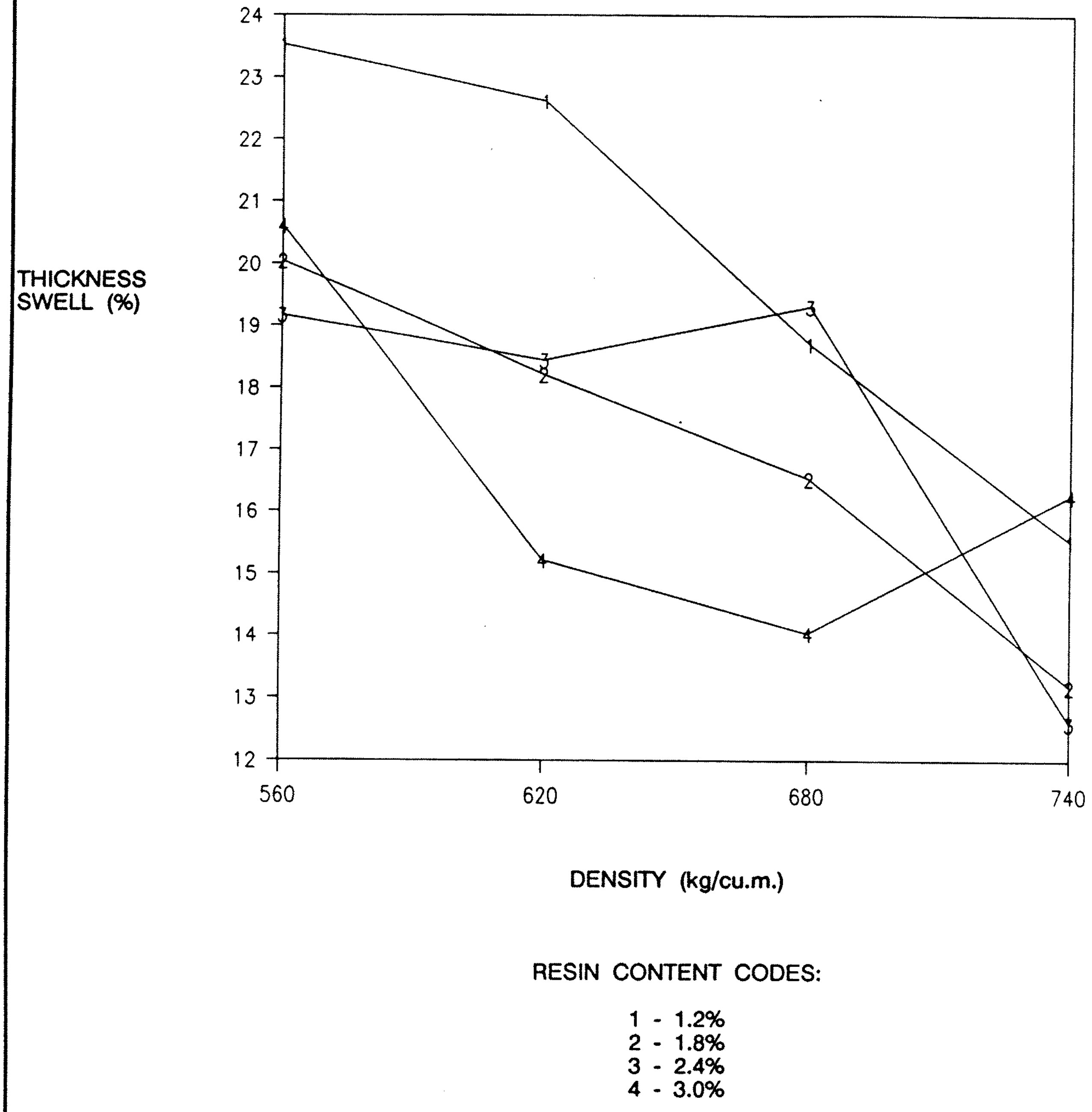
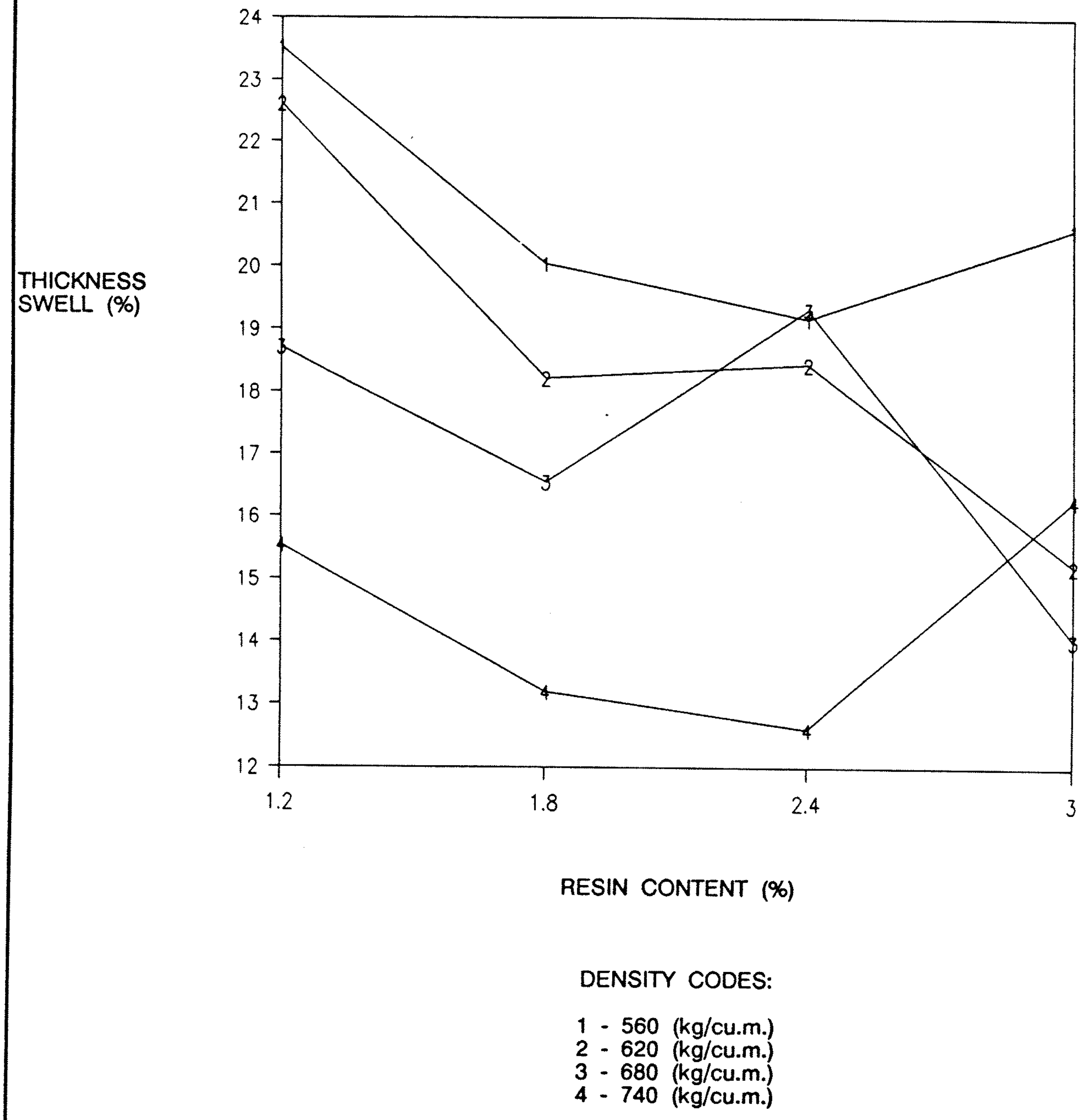


FIGURE 12. THICKNESS SWELL VS. RESIN CONTENT AND DENSITY

EFFECTS OF DENSITY SHOWN BY FAMILY OF CURVES



5.2.6 Linear Expansion

Linear Expansion shows poor trends, and insignificant differences between classes, for both density class and resin class (refer to Figure 13 and 14, Table 8).

Table 8: Linear Expansion (%)

DENSITY CLASS (kg/cu.m.)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
560	.2549	b
620	.2395	a b
680	.2356	a b
720	.2195	a

RESIN CLASS (%)	AVERAGE DRY MOE (M.Pa.)	HOMOGENOUS SUBSETS
1.2	.2613	b
1.8	.2344	a
2.4	.2294	a
3.0	.2245	a

Details for raw data on which table is based are in Appendix III.
For statistical evaluation of same see Appendix IV.

FIGURE 13. LINEAR EXPANSION VS. DENSITY AND RESIN CONTENT

EFFECTS OF RESIN CONTENT SHOWN BY FAMILY OF CURVES

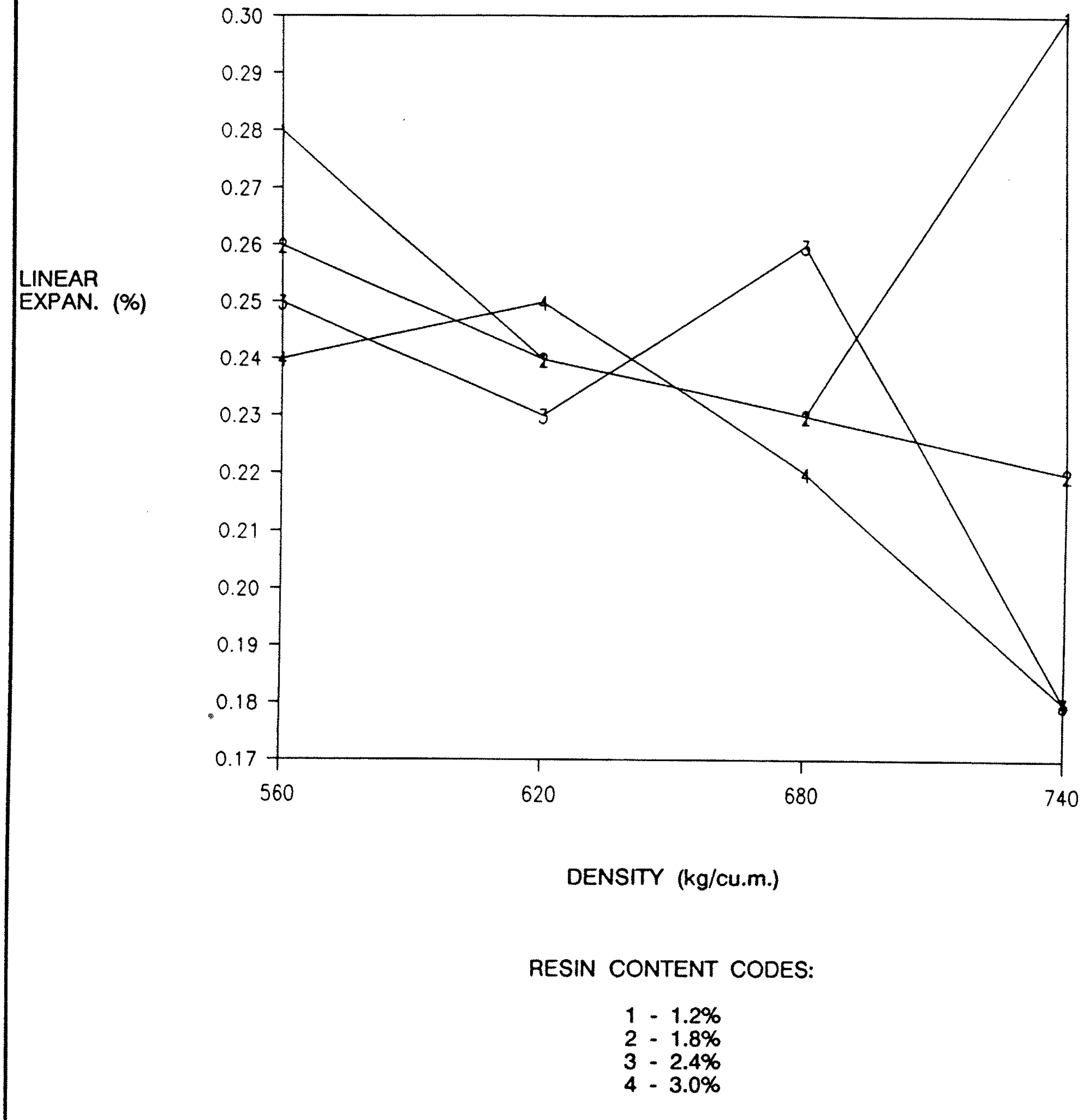
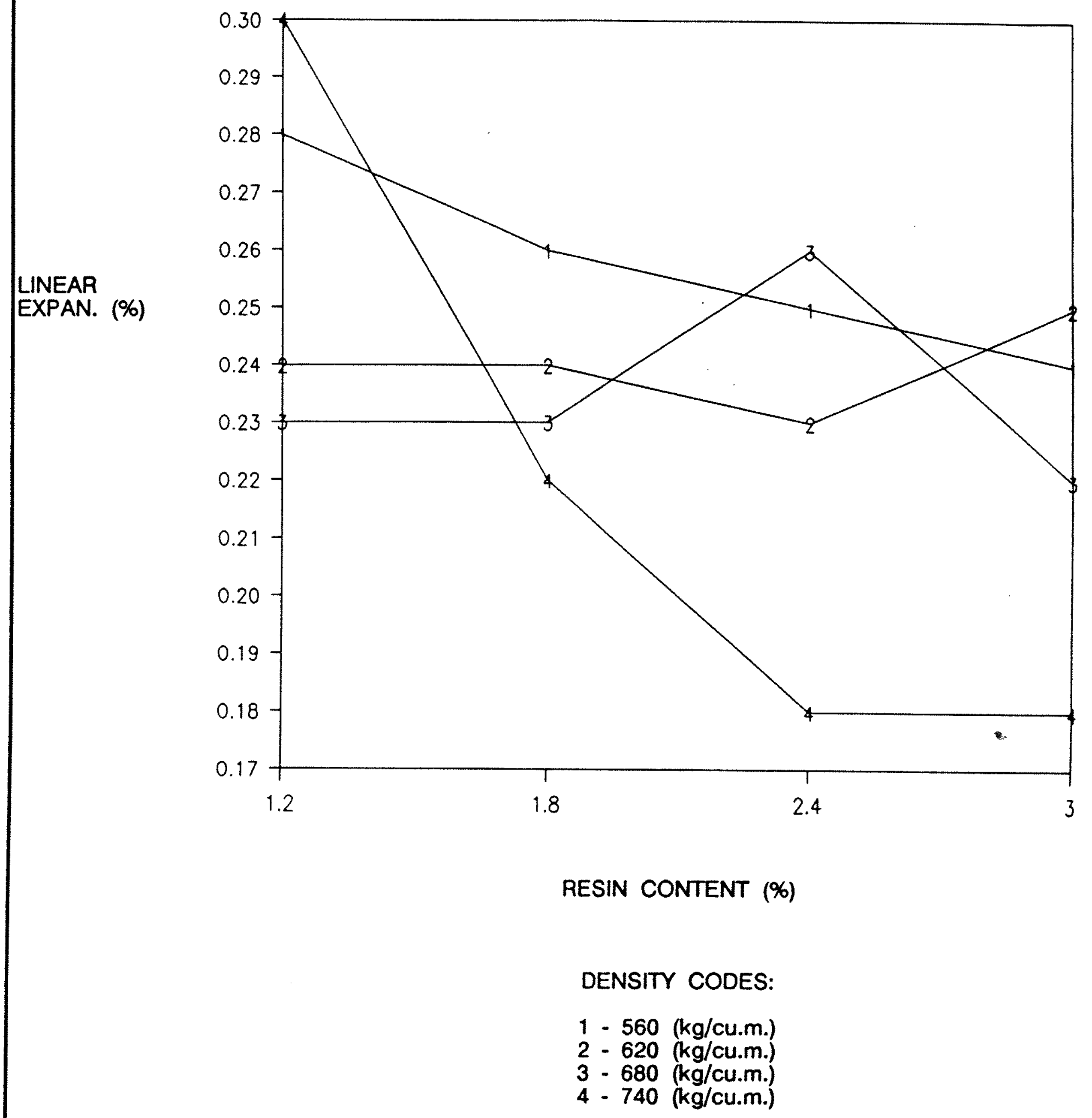


FIGURE 14. LINEAR EXPANSION VS. RESIN CONTENT AND DENSITY

EFFECTS OF DENSITY SHOWN BY FAMILY OF CURVES



6. CONCLUSIONS

Before the current project was undertaken, PANELMAX, the panelboard production optimization model, used data presented in publically available technical literature. Because the data resulted from a number of researchers and numerous different laboratories, consistency and applicability of results was poor. The initial development of a database through this project by the Alberta Research Council is a significant step towards making PANELMAX usable everyday by Alberta's panel industry. Continued development of this data base will greatly enhance the model, providing consistent, high quality inputs to the computer program. Through sensitivity analyses, PANELMAX will feed information back to the researchers at Alberta Research Council, indicating the industrial (economic) significance of the different process variables thus providing guidance regarding which process variables warrant further attention in future testing programs.

The statistical analysis of the data revealed very strong relationships between MOR (dry and 2 hour boil) and density; between MOE and density; and between internal bond and resin content. Weaker relationships were found between MOR (dry and 2 hour boil) and resin content; between MOE and resin content; and between internal bond and density. The results of the thickness swell and linear expansion tests are much less conclusive, with few strong trends being identified. The data generated by these tests is well suited for inclusion into the PANELMAX model, and is presently being incorporated into the model.

7. COMMERCIAL SIGNIFICANCE

Opimization of panel manufacture will allow more economical production. Use of this system allows informal decisions to be made with respect to attaining target levels.

An important fact shown by the work described in this report is that neither resin content nor density uniformly affected all properties tested. Most properties were above allowable levels, which puts the onus on the manufacturers to establish reasonable target levels for properties before production can be optimized to reach these levels.

Expanding the use of this model to cover performance properties could assist the manufacturers in defining these targets, as some properties are less significant that others, but performance test results leave absolute target values.

8. RECOMMENDATIONS

The definite relationships shown by this work indicate the value of further work on defining the effects of basic process variables on panel properties.

Potential areas for further work include:

- Expansion of the variables to include wafer geometry and press closing speed.
- Expansion of criteria to include performance properties.
- Convert PANELMAX to an IBM PC program, disks and manual, enabling more general use by industry.
- Joint venture with a manufacturer to use the system to:
  (a) monitor and plan
  (b) process control

9. ACKNOWLEDGEMENTS

The financial contribution to the Alberta Research Council's Forest Products Research and Development Program from the Alberta Forest Service (Alberta Forestry) and the Canadian Forestry Service (Agriculture Canada) is greatly appreciated.

10. REFERENCES

Grabowski, T.I.G., T.E. Daniel, and C.T.L. Janssen. 1986. Optimization of the Waferboard Production Process, In: Production Management: Methods and Studies. B. Lev (Editor). Elsevier Science Publishers B.V. (North-Holland).

Grabowski, T.I.G., 1983. An optimization model for waferboard production. Final Report for ARC Project FP-19. Alberta Research Council, Forest Products Program. Edmonton, Alberta.

Grabowski, T.I.G., 1982. An optimization model for waferboard production. M.B.A. thesis, University of Alberta Faculty of Business Administration and Commerce.

APPENDIX I

REICHHOLD TECHNICAL BULLETIN FOR IB-947 PHENOLIC POWDERED RESIN

REICHHOLD **Technical Bulletin**

Reichhold Limited
4 Robert Speck Parkway, Suite 700
Mississauga, Ontario L4Z 1S1
Telex: 06-960282

IB-947 PHENOLIC POWDER

IB-947 PHENOLIC POWDERED RESIN FOR THE MANUFACTURE OF WAFERBOARD/OSB

IB-947 is a fast curing, one-step powdered phenolic resin especially developed for the waferboard/OSB industry. It is most often used as a core resin in conjunction with a surface resin such as IB-948 or BD-003 but may be used in single resin systems throughout the panel.

POWDER PROPERTIES:

Colour: Pink
Form of Compound: Very Fine Powder
Screen Test (R.L. Test Method): 85% through 200 mesh
Storage Life: 3-4 months at 20°C

GENERAL SPECIFICATIONS:

Hot Plate Cure at 150°C:	10-20 seconds
Softening Point (Capillary):	85-95°C

STORAGE AND SHIPPING:

Resin being of a hygroscopic nature, it is recommended to store in cool dry place - temperature not exceeding 20°C. Shipped in multi-wall paper bags or tote bags.

SPECIAL HANDLING PRECAUTIONS:

Avoid prolonged contact with the skin. The use of goggles and dust masks are recommended when handling powdered resins.

If powder comes in contact with the skin, it should be washed off with warm water and soap. Cleanliness is important.

SAFETY BULLETIN:

Bulletins are available on request.

JUNE 1985

APPENDIX II

PLOTS OF PRESS CYCLES FOR PANELS OF VARYING RESIN AND DENSITIES LEVELS

FIGURE II-1: Typical Press Cycle Profile for Panels of 560 kg/m^3 and 1.2% Resin Content

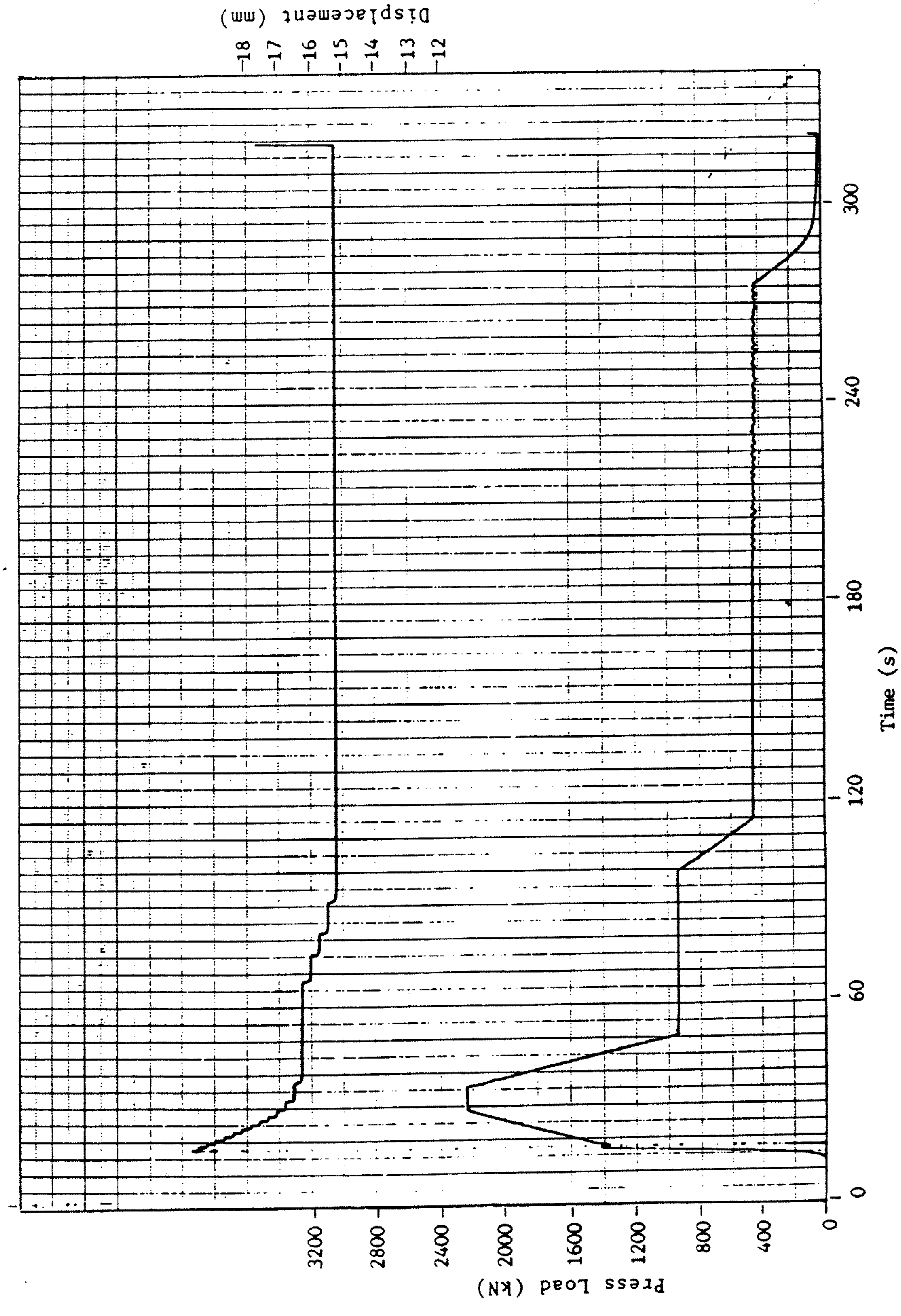


FIGURE II-2: Typical Press Cycle Profile for Panels of 620 kg/m^3 and 1.2% Resin Content

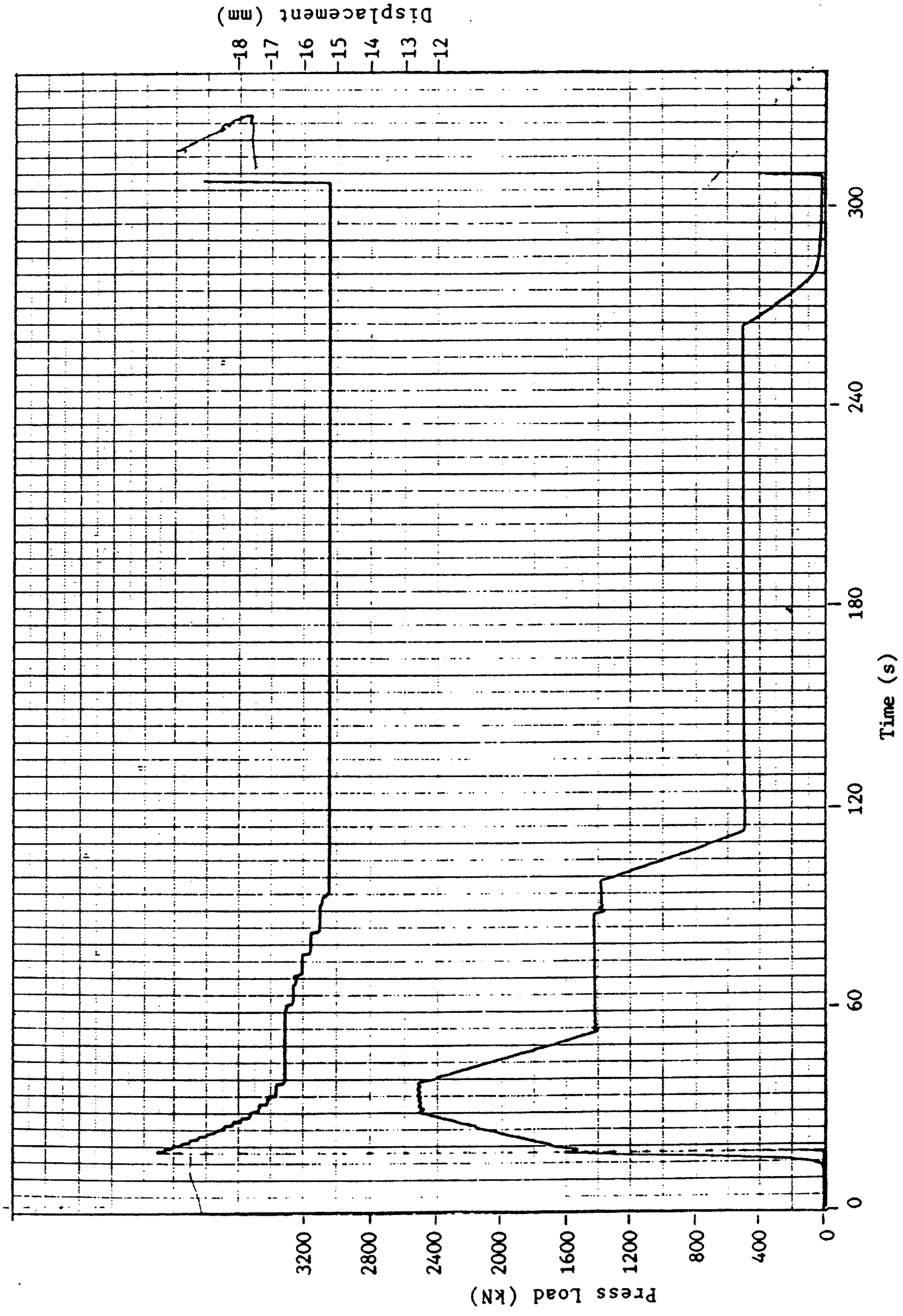


FIGURE II-3: Typical Press Cycle Profile for Panels of 680 kg/m^3 and 1.2% Resin Content

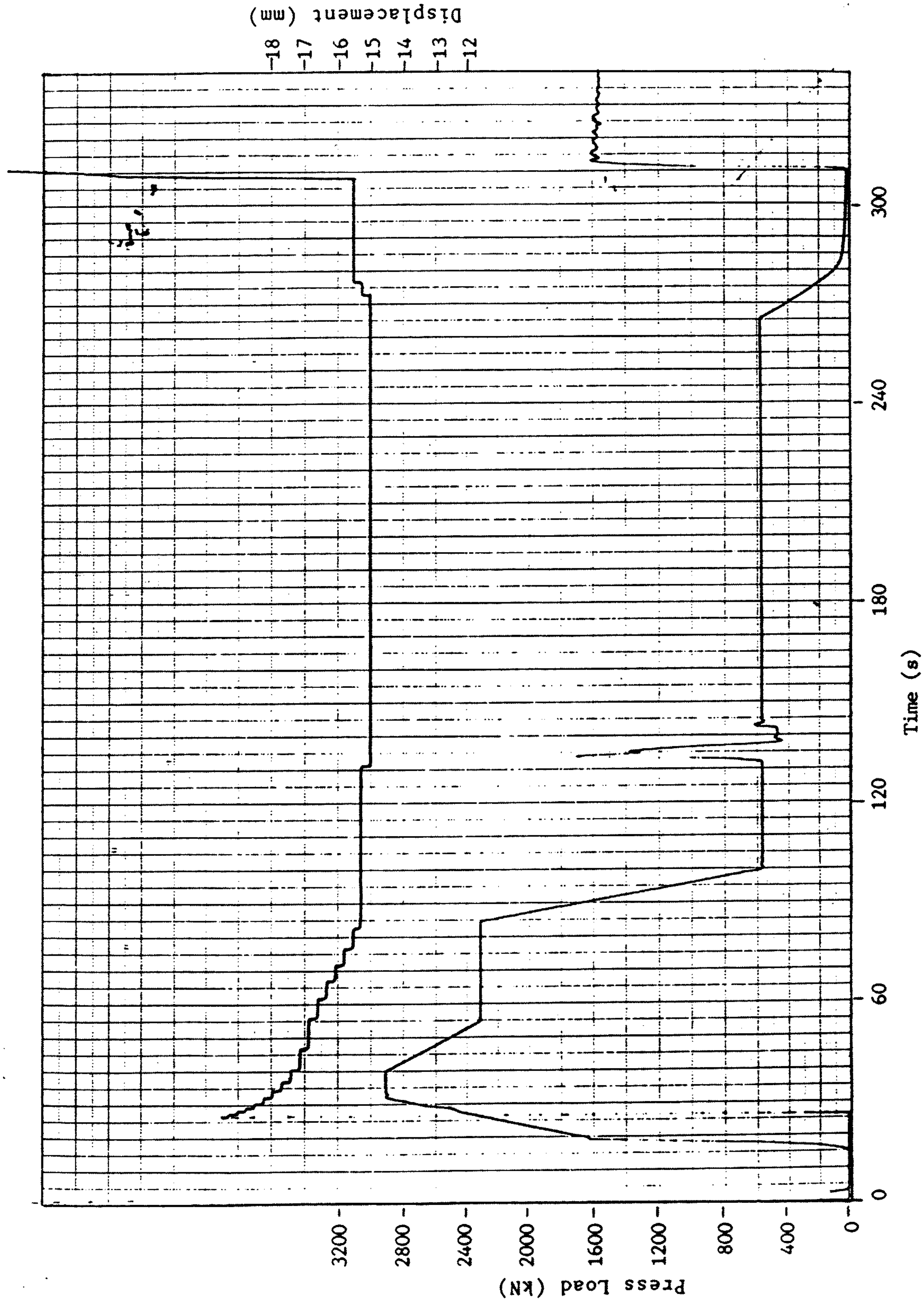


FIGURE II-4: Typical Press Cycle Profile for Panels of 680 kg/m^3 and 1.8% Resin Content

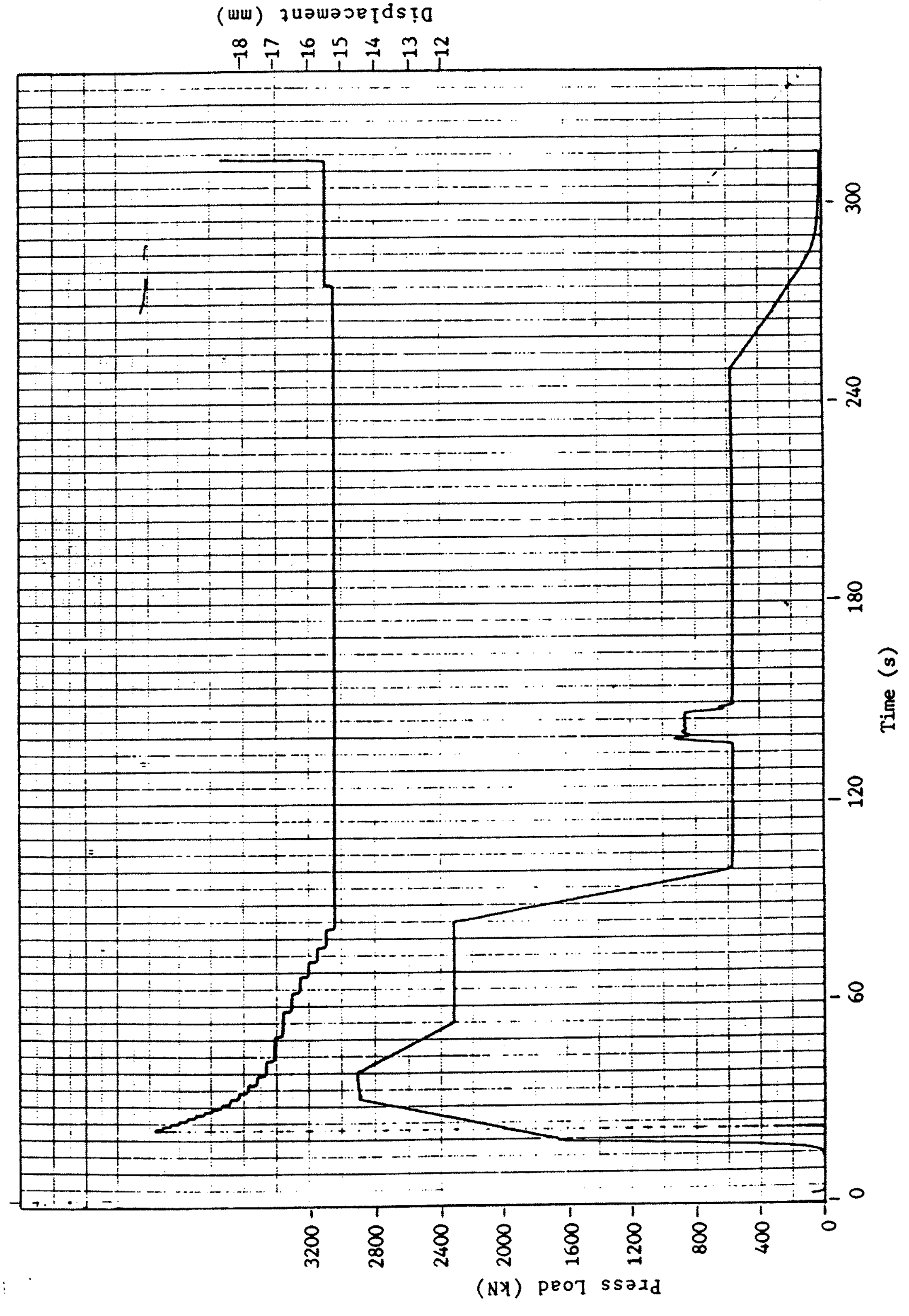


FIGURE II-5: Typical Press Cycle Profile for Panels of 740 kg/m^3 and 1.8% Resin Content

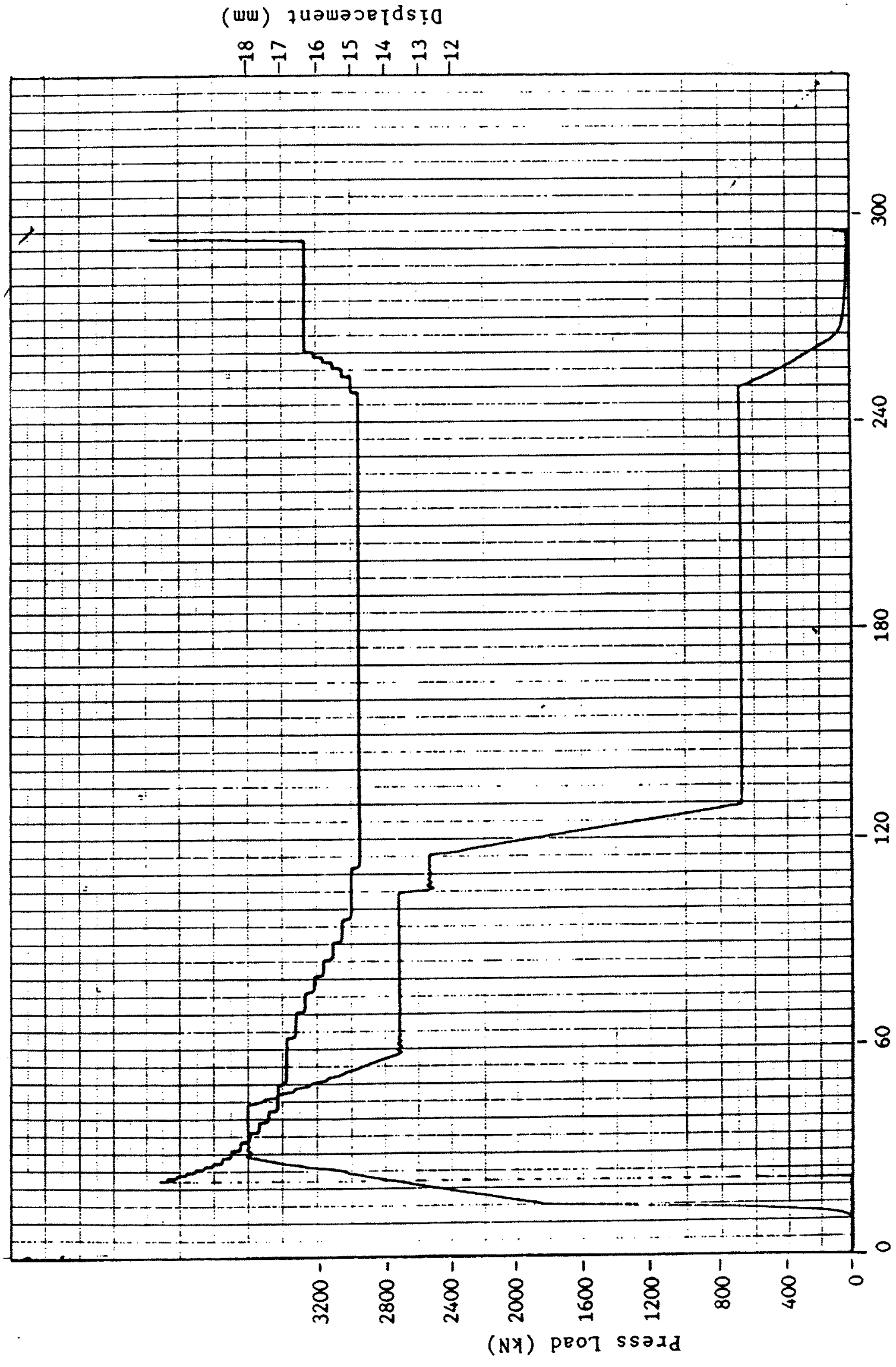


FIGURE II-6: Typical Press Cycle Profile for Panels of 560 kg/m^3 and 2.4% Resin Content

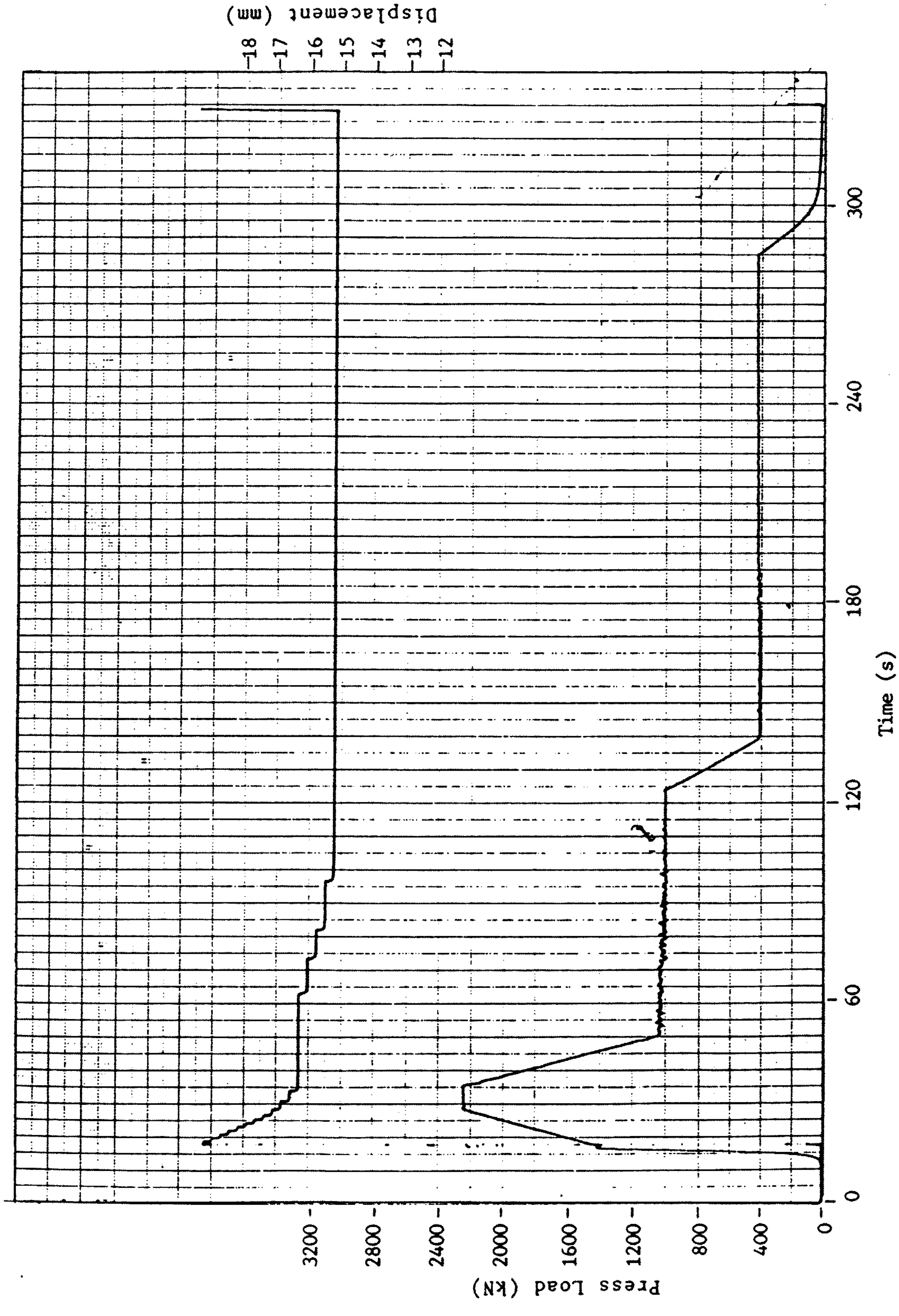


FIGURE II-7: Typical Press Cycle Profile for Panels of 740 kg/m^3 and 2.4% Resin Content

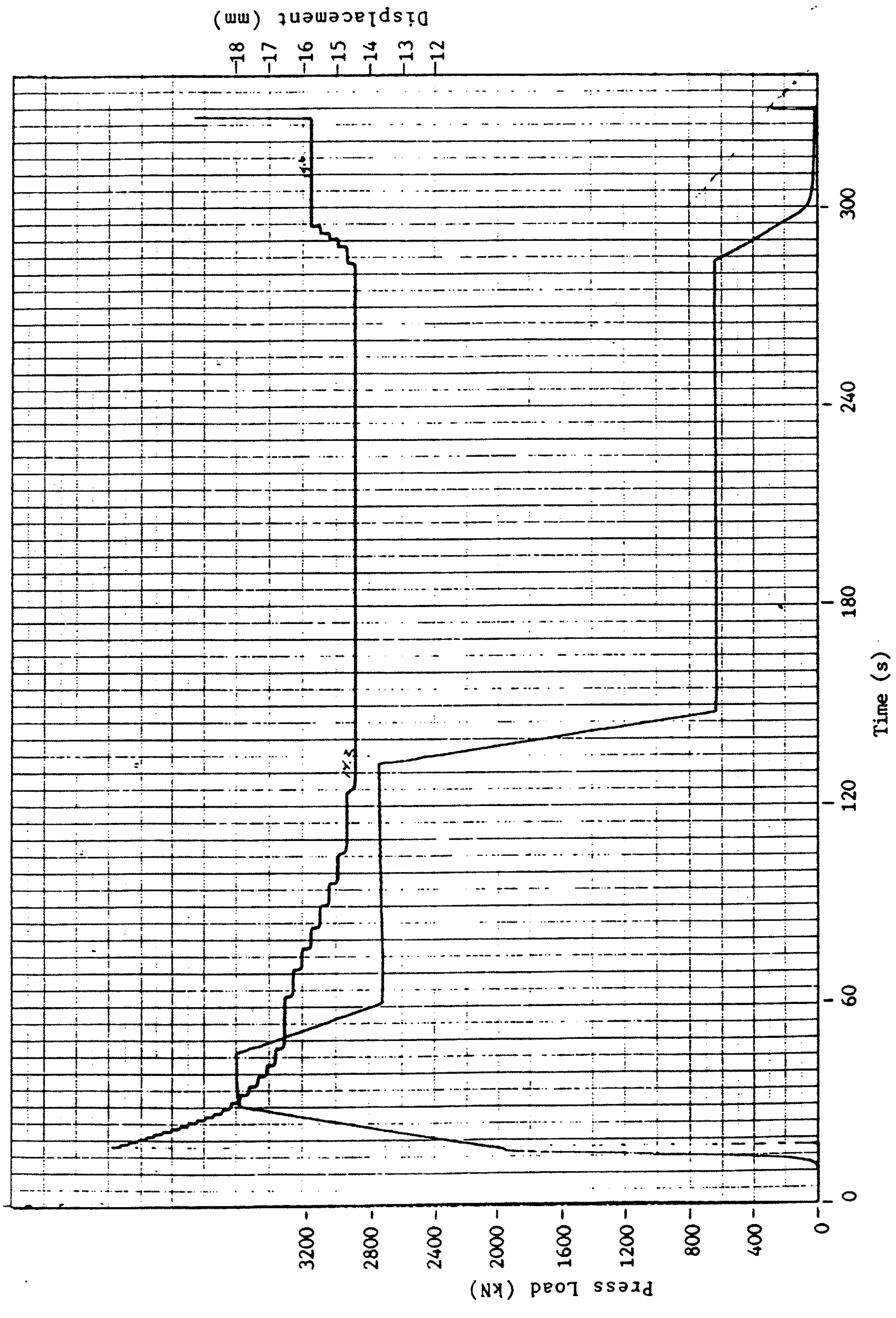


FIGURE II-8: Typical Press Cycle Profile for Panels of 560 kg/m^3 and 3.0% Resin Content

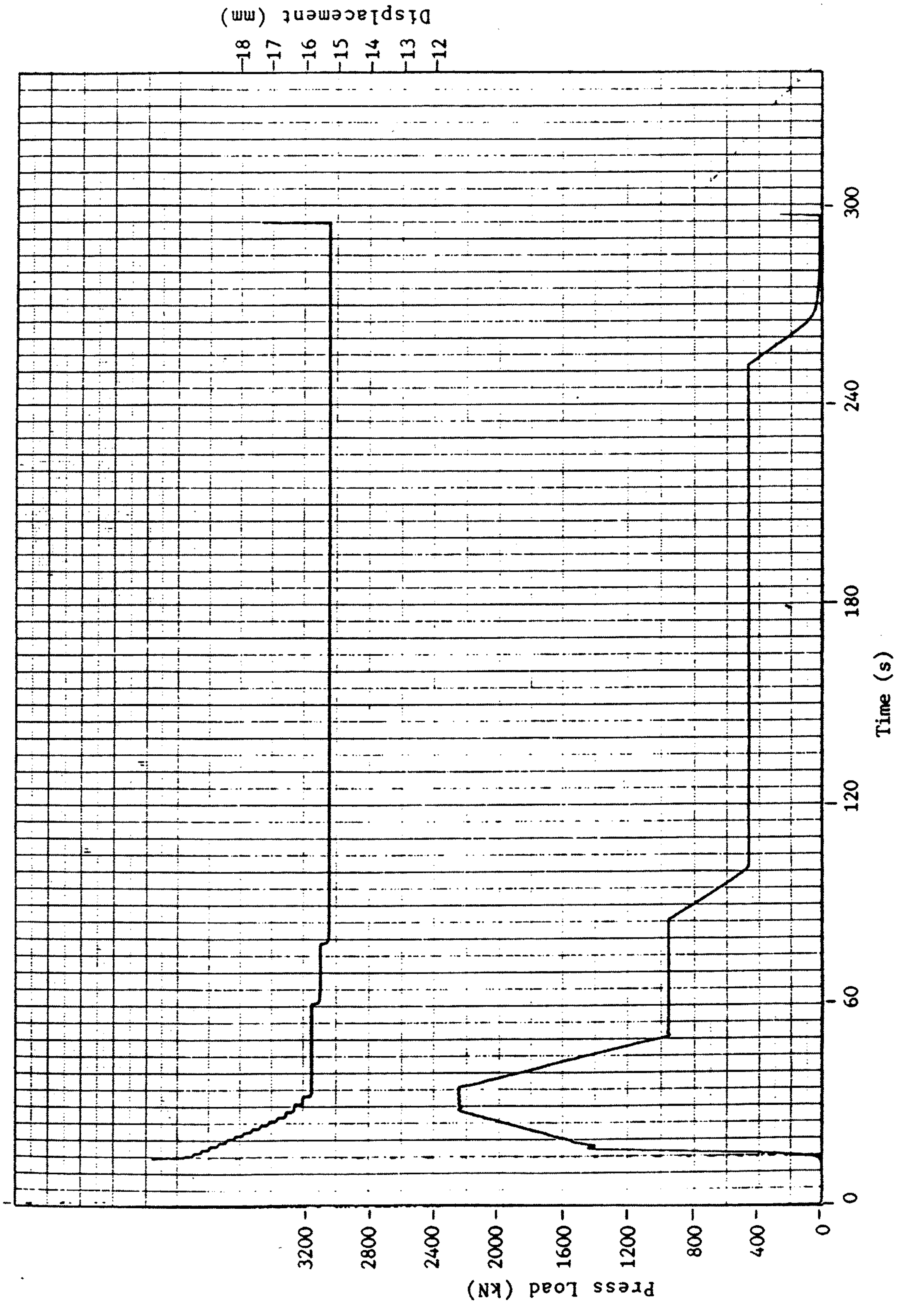


FIGURE II-9: Typical Press Cycle Profile for Panels of 620 kg/m^3 and 3.0% Resin Content

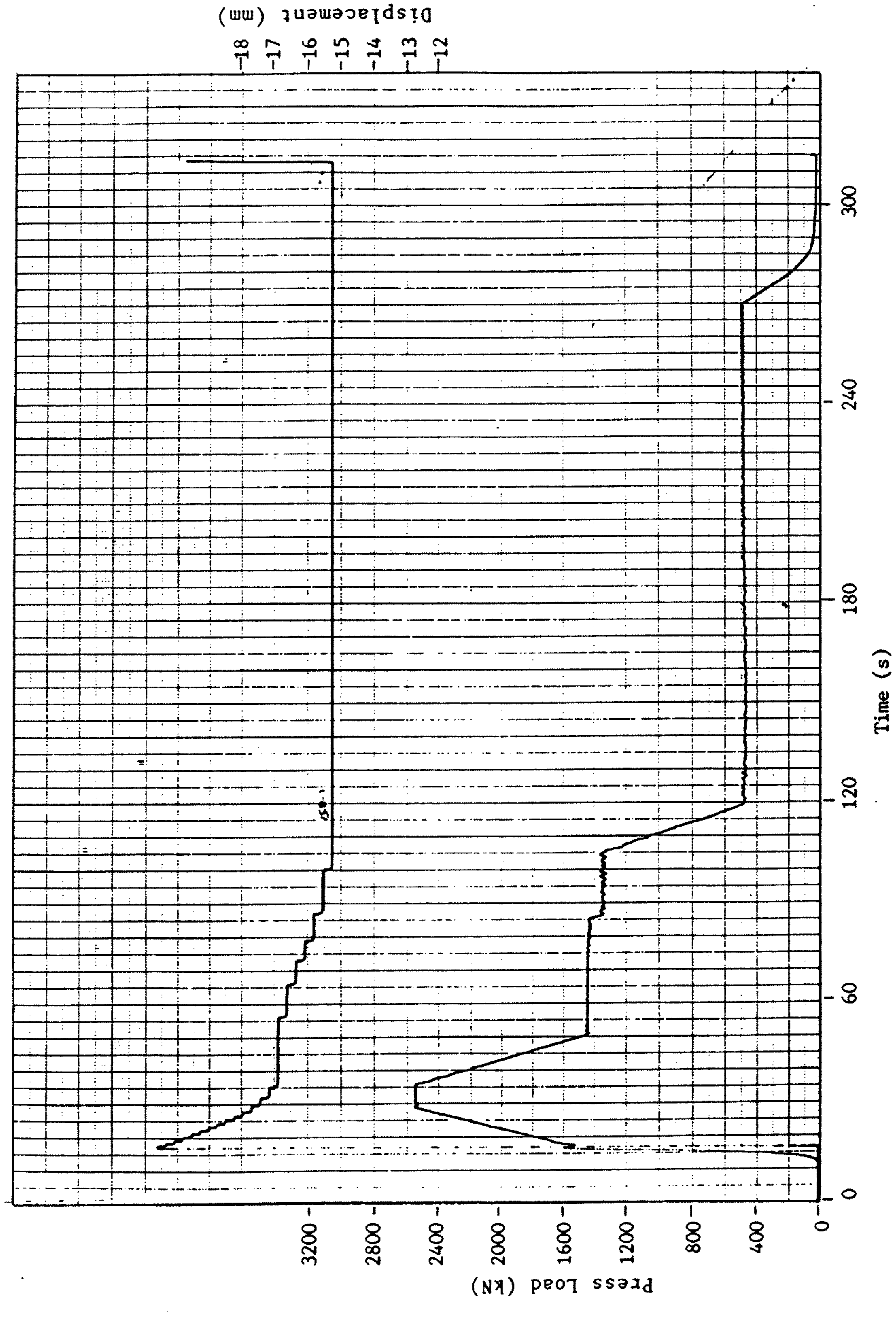


FIGURE II-10: Typical Press Cycle Profile for Panels of 680 kg/m^3 and 3.0% Resin Content

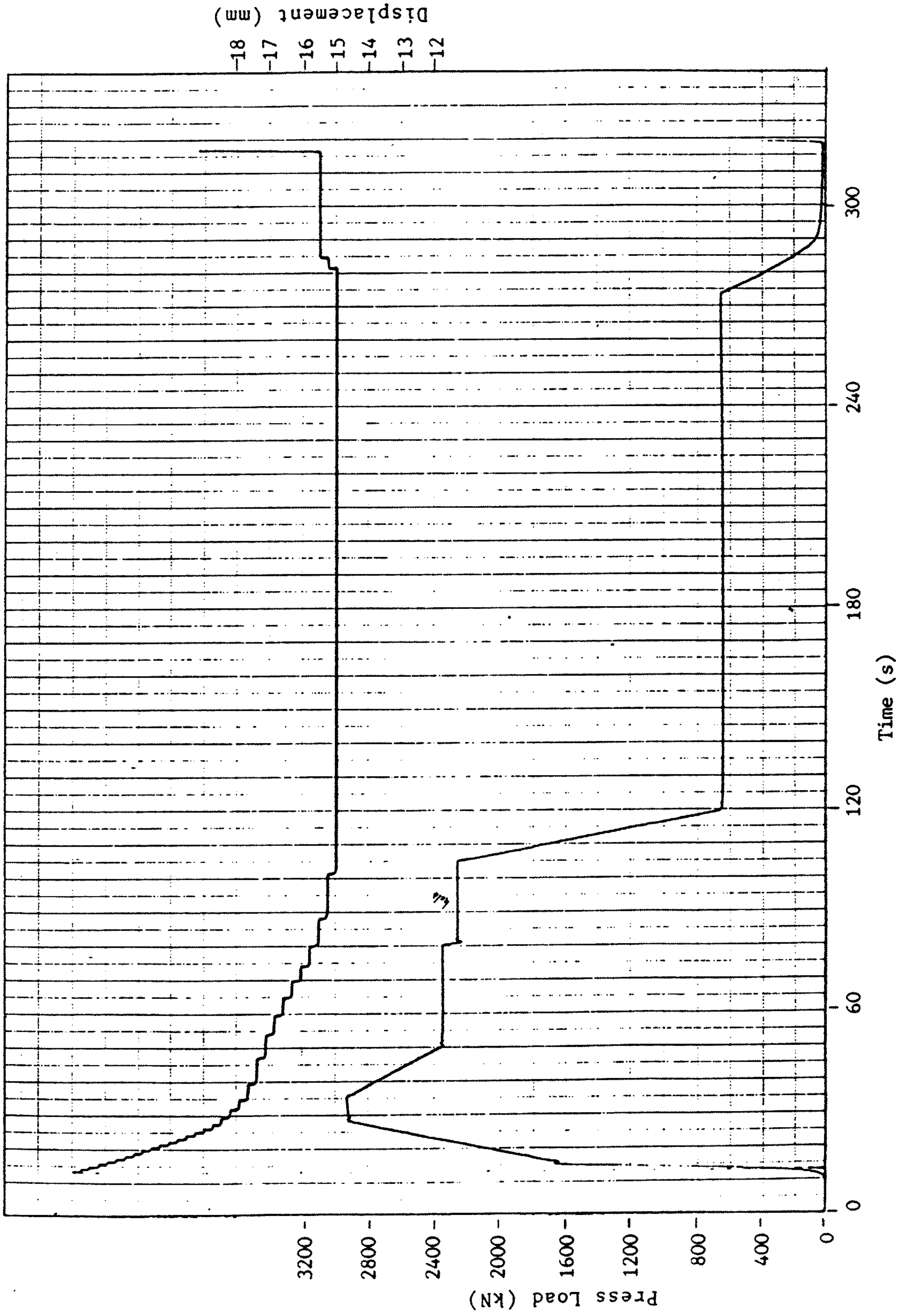
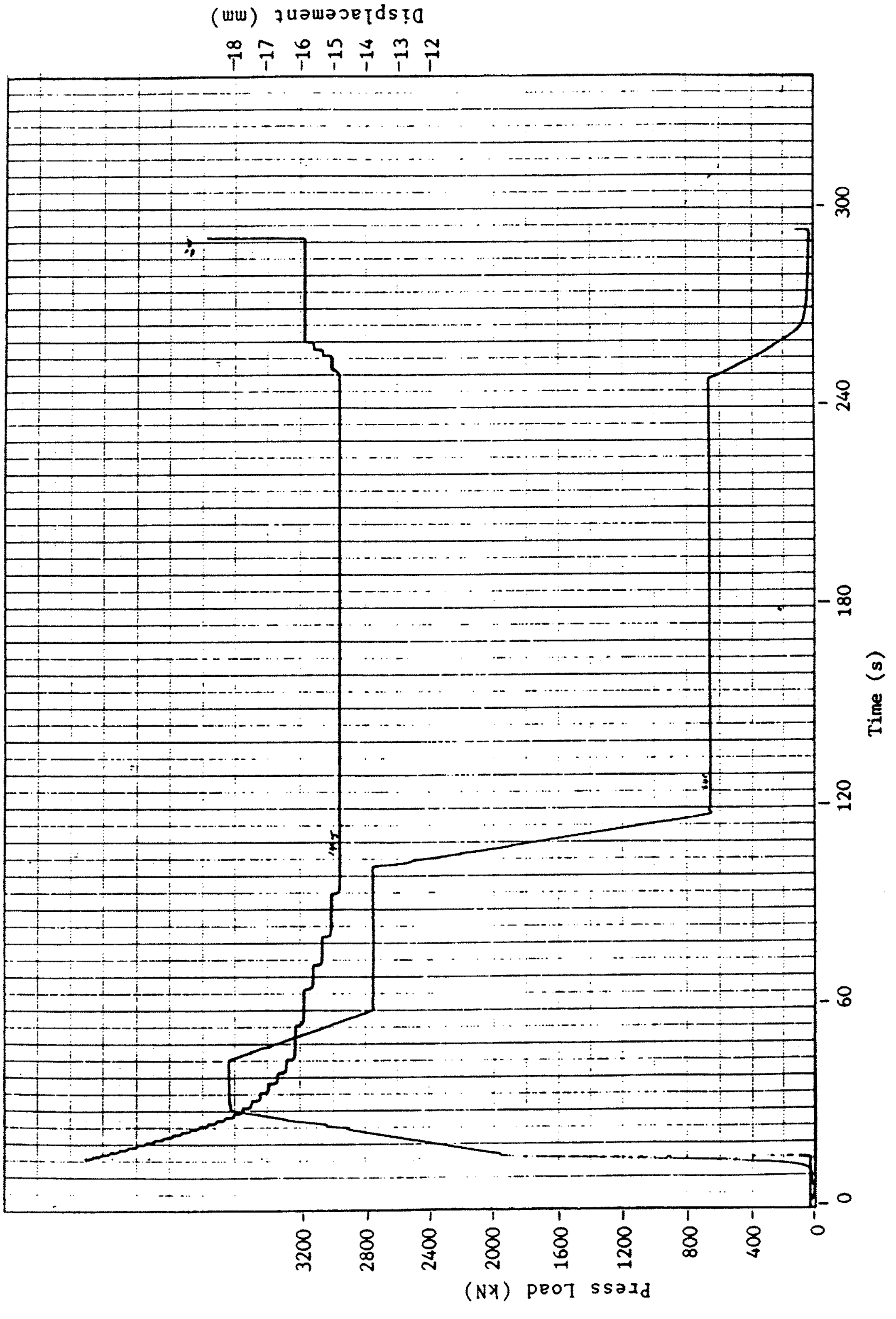


FIGURE II-11: Typical Press Cycle Profile for Panels of 740 kg/m^3 and 3.0% Resin Content



APPENDIX III

DATA SUMMARY

DRY MOR (M.Pa.)

DENSITY	RESIN	AVERAGE	STD DEV	MAXIMUM	MINIMUM	NUMBER
560	1.2	20.7	4.0	28.4	13.1	30
560	1.8	23.7	4.1	33.3	14.6	30
560	2.4	25.2	3.7	33.2	18.2	30
560	3.0	26.6	4.7	34.2	16.7	30
620	1.2	24.7	3.3	31.9	16.7	30
620	1.8	30.1	3.8	38.5	21.8	30
620	2.4	30.5	4.6	39.5	18.5	30
620	3.0	31.7	4.6	48.2	21.4	30
680	1.2	29.2	3.5	38.1	23.1	30
680	1.8	33.7	4.6	44.2	25.1	30
680	2.4	35.3	5.4	47.4	24.5	30
680	3.0	37.5	5.7	48.0	22.6	30
740	1.2	31.8	4.2	43.6	25.1	30
740	1.8	39.1	6.4	52.6	28.5	30
740	2.4	38.4	4.0	47.4	31.7	30
740	3.0	41.2	5.2	51.5	30.5	30

DRY MOE (M.Pa.)

DENSITY	RESIN	AVERAGE	STD DEV	MAXIMUM	MINIMUM	NUMBER
560	1.2	4043	516	5000	3100	30
560	1.8	4067	482	5000	3200	30
560	2.4	4113	544	5300	3100	30
560	3.0	4147	464	5300	3100	30
620	1.2	4543	457	5600	3600	30
620	1.8	5103	550	6100	4000	30
620	2.4	4727	451	5500	3400	30
620	3.0	4803	466	5900	3800	30
680	1.2	5113	582	6400	4100	30
680	1.8	5383	609	6800	4200	30
680	2.4	5270	568	6500	4100	30
680	3.0	5370	583	6400	4200	30
740	1.2	5233	631	7400	4300	30
740	1.8	6003	609	7400	4900	30
740	2.4	5643	496	6700	4800	30
740	3.0	5920	601	7300	4400	30

MOR - 2 HOUR BOIL (M.Pa.)

DENSITY	RESIN	AVERAGE	STD DEV	MAXIMUM	MINIMUM	NUMBER
560	1.2	11.2	1.9	15.6	7.4	30
560	1.8	14.0	2.6	18.6	10.3	30
560	2.4	13.1	2.4	18.3	7.6	30
560	3.0	14.6	2.6	19.3	8.3	30
620	1.2	13.0	1.7	16.6	9.8	30
620	1.8	17.4	2.3	23.0	14.0	30
620	2.4	17.2	2.6	23.2	11.8	30
620	3.0	18.4	2.5	25.5	13.4	30
680	1.2	16.0	1.8	19.9	11.3	30
680	1.8	19.1	2.2	23.9	14.5	30
680	2.4	19.7	2.9	29.7	15.0	30
680	3.0	21.9	3.0	29.4	16.7	30
740	1.2	17.4	2.7	22.9	10.3	30
740	1.8	21.4	3.0	27.2	14.7	30
740	2.4	21.4	2.1	25.1	16.6	30
740	3.0	22.6	2.5	29.1	19.1	30

INTERAL BOND (M.Pa.)

DENSITY	RESIN	AVERAGE	STD DEV	MAXIMUM	MINIMUM	NUMBER
560	1.2	0.346	0.047	0.442	0.262	30
560	1.8	0.419	0.067	0.516	0.242	30
560	2.4	0.539	0.060	0.696	0.444	30
560	3.0	0.594	0.072	0.709	0.382	30
620	1.2	0.377	0.055	0.486	0.251	30
620	1.8	0.487	0.068	0.597	0.295	30
620	2.4	0.621	0.066	0.751	0.502	30
620	3.0	0.673	0.060	0.820	0.553	30
680	1.2	0.419	0.067	0.551	0.269	30
680	1.8	0.500	0.069	0.644	0.387	30
680	2.4	0.602	0.060	0.736	0.505	30
680	3.0	0.699	0.067	0.845	0.592	30
740	1.2	0.391	0.061	0.526	0.275	30
740	1.8	0.540	0.066	0.662	0.425	30
740	2.4	0.675	0.087	0.810	0.433	30
740	3.0	0.642	0.077	0.766	0.469	30

THICKNESS SWELL (%)

DENSITY	RESIN	AVERAGE	STD DEV	MAXIMUM	MINIMUM	NUMBER
560	1.2	23.53	3.06	29.72	16.74	40
560	1.8	20.04	3.14	25.58	13.76	40
560	2.4	19.17	2.15	24.67	15.21	40
560	3.0	20.61	3.46	30.14	12.89	40
620	1.2	22.62	3.85	32.27	16.74	40
620	1.8	18.22	2.59	25.70	12.68	40
620	2.4	18.45	2.93	26.94	12.96	40
620	3.0	15.23	2.51	23.87	11.93	40
680	1.2	18.71	4.57	30.09	12.83	40
680	1.8	16.55	3.24	23.18	10.39	40
680	2.4	19.32	3.70	29.86	12.72	40
680	3.0	14.04	2.20	20.09	10.60	40
740	1.2	15.54	2.97	26.82	11.06	40
740	1.8	13.20	3.39	20.80	6.67	40
740	2.4	12.61	2.13	17.09	9.29	40
740	3.0	16.28	3.35	23.11	9.21	40

LINEAR EXPANSION (%)

DENSITY	RESIN	AVERAGE	STD DEV	MAXIMUM	MINIMUM	NUMBER
560	1.2	0.28	0.05	0.40	0.23	20
560	1.8	0.26	0.03	0.32	0.19	20
560	2.4	0.25	0.03	0.30	0.19	20
560	3.0	0.24	0.05	0.34	0.19	20
620	1.2	0.24	0.03	0.30	0.19	20
620	1.8	0.24	0.04	0.32	0.17	20
620	2.4	0.23	0.04	0.32	0.17	20
620	3.0	0.25	0.06	0.34	0.13	20
680	1.2	0.23	0.03	0.30	0.19	20
680	1.8	0.23	0.04	0.34	0.17	20
680	2.4	0.26	0.04	0.34	0.21	20
680	3.0	0.22	0.04	0.30	0.15	20
740	1.2	0.30	0.04	0.38	0.23	20
740	1.8	0.22	0.04	0.34	0.15	20
740	2.4	0.18	0.03	0.25	0.13	20
740	3.0	0.18	0.02	0.21	0.13	20