A DYNAMIC TESTER FOR FOLDING BOXBOARD SCORELINES

Thesis for the Degree of M. S.
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Howard Colburn Blake III

1960

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By

Howard Colburn Blake III

AN ABSTRACT

Submitted to the College of Agriculture of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Forest Products

1960

Approved : James W. Goff

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This study was undertaken to develop a testing device which would evaluate folding boxboard scorelines.

The tester developed bends specimens of folding boxboard scorelines at rates approximating set-up machinery speeds. The angle through which the specimens are bent is also controlled.

The force required to bend a scoreline through any given angle is presented in the form of an oscillograph trace. The force measurements are made by employing bonded strain gages.

Three scoring variables were used on selected specimens in order to demonstrate the device. These variables were MANICO dies versus engraved steel plate dies, seven testing speeds, and scores running parallel to and perpendicular to the machine or grain direction of the specimen board.

The tester illustrated that scorelines running parallel to the machine direction of the board were less resistant to bending than those running perpendicular to the machine direction. The scorelines made on engraved steel dies were more resistant to bending than were those scorelines produced on MANICO dies. This was because of a difference in female die width and depth of the scorelines.

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Finally this writer is grateful to his wife for her encouragement and assistance throughout the course of this work.

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INTRODUCTION

The folding box industry has long sought a laboratory method of testing and evaluating folding boxboard scorelines which would correlate satisfactorily with machine runs. A fast, simple method of testing sample scorelines would enable manufacturers of folding boxes to make the correct selection of rule and makeready at the beginning of the production run. Since the scores determine the performance of a folding box in the set-up machinery, proper selection of rule and makeready is important to obtain a uniform run.

The device herein described was developed to test scored boxboard up to and including 0.040 inch thickness. The speed of testing may be varied as can the angle of deflection through which the specimen is bent. Permanent records of the bending force plotted against the angle of deflection may be obtained in photographic form. Springback may be read either from the photographic record or from a vernier type drum dial.

The specimens used were cut from 0.032 inch thick bending chipboard with a 60 pound per 1000 square feet printed liner wax-laminated to it.

The method of testing employed was to bend the specimens with the device herein described in order to demonstrate its effectiveness. The testing of these specimens was not conducted to evaluate or compare any materials or combination of variables. The purpose was to demonstrate the use of the device and its ability to show changes in scoreline performance as the scoring variables are changed (A).

(A) For a list of scoring variables refer to Appendix B.

PREVIOUS WORK

Until the middle 1950's, no method of testing scorelines existed except the classic hand and eye method. This procedure involved bending a scoreline and observing the bead formation along the inside of the scoreline. Whether or not the scoreline was too resistant to bending depended entirely on the bender's judgment.

In March of 1956, the Boxboard Research Associates designed a bending tester employing principles originally developed by the Ohio Boxboard Company (3). This procedure paralleled the classic procedure except that rule width, makeready width, and depth of penetration were closely controlled and varied. This allowed any number of these variables to be studied at the same time while employing the same board. Strips of board were scored in several bays of the press, each bay being set up differently. The specimens were then hand folded and compared one against another.

D. J. Hine of PATRA developed a scoreline tester employing several conditions encountered in an automatic packaging line (1). The force required to bend a scoreline was measured by unbonded strain gages. The angular deflection of the specimen was measured by a voltage drop across a 30,000 ohm potentiometer. An oscillograph trace was obtained by feeding the strain gage and voltage drop signals into the oscillograph. Some variations in testing speeds were also available.

The Ohio Boxboard Score Bend Tester was originally designed to determine the force necessary to set up folding boxes whose side seam had been glued (2). The process was simply to apply force to one corner of a glued blank and measure the amount of force transmitted to the diagonal edge. Later modifications have allowed the force necessary to bend a scored flap to be measured.

G. L. Schulz developed a method for testing score-lines using a Baldwin FGT-SR-4 Universal Testing Machine (4). This procedure also employed an auxillary 500 pound capacity load cell. The specimens were bent at the rate of four inches per minute. An automatic recorder plotted bending force against angular deflection. Springback was measured by means of a protractor after the specimens were removed from the holders.

In February 1959, the Marathon Corporation developed a machine which compared specimens of scored board against specimens of unscored board (5). The resulting value represented the force necessary to bend the scored specimen as a percentage of the force necessary to bend the unscored specimen. The specimens to be tested were placed across two parallel, horizontal knife edges so that the scoreline ran parallel to the knives and was centered between them. A third knife edge was placed above the specimen and on top of the score. The base knives were raised causing the specimen to bend along the single knife edge above. The single knife was attached to a strain gage network which emitted a signal in direct proportion to the force necessary to bend the board. This signal was amplified and recorded.

SCORELINE TESTER DESCRIPTION

Specimen Holders

The specimen holders were designed to accommodate boxboard up to and including 0.040 inch thickness. The specimen size used was one inch by two and one-half inches with the scoreline running parallel to the one inch dimension. The scoreline was one inch from the end of the specimen.

The holders were constructed of 2424ST aluminum stock. They were L-shaped cantilever beams with a stiffening member added to increase rigidity. The beams were positioned on adjacent spur gears so that the flat surfaces of the longer beam legs form a plane. The surface of this plane lay 0.020 inch below the center of the spur gear axis and parallel to the tester's base plate. The specimens were held by means of plates which lay parallel to the holders' surfaces. Shim stock was used to raise or lower the specimen so that a plane which passed through the center of the specimen's thickness also passed through the spur gear axis.

Torque Measurement (Bending Force)

The force needed to bend the scoreline of a specimen was measured by a strain gage bridge. The gages were mounted on a cantilever beam which was delfected by one of the specimen holders as the scoreline was bent. The bridge consisted of four Baldwin-Lima-Hamilton SR-4

FIGURE 1. SPECIMEN HOLDERS

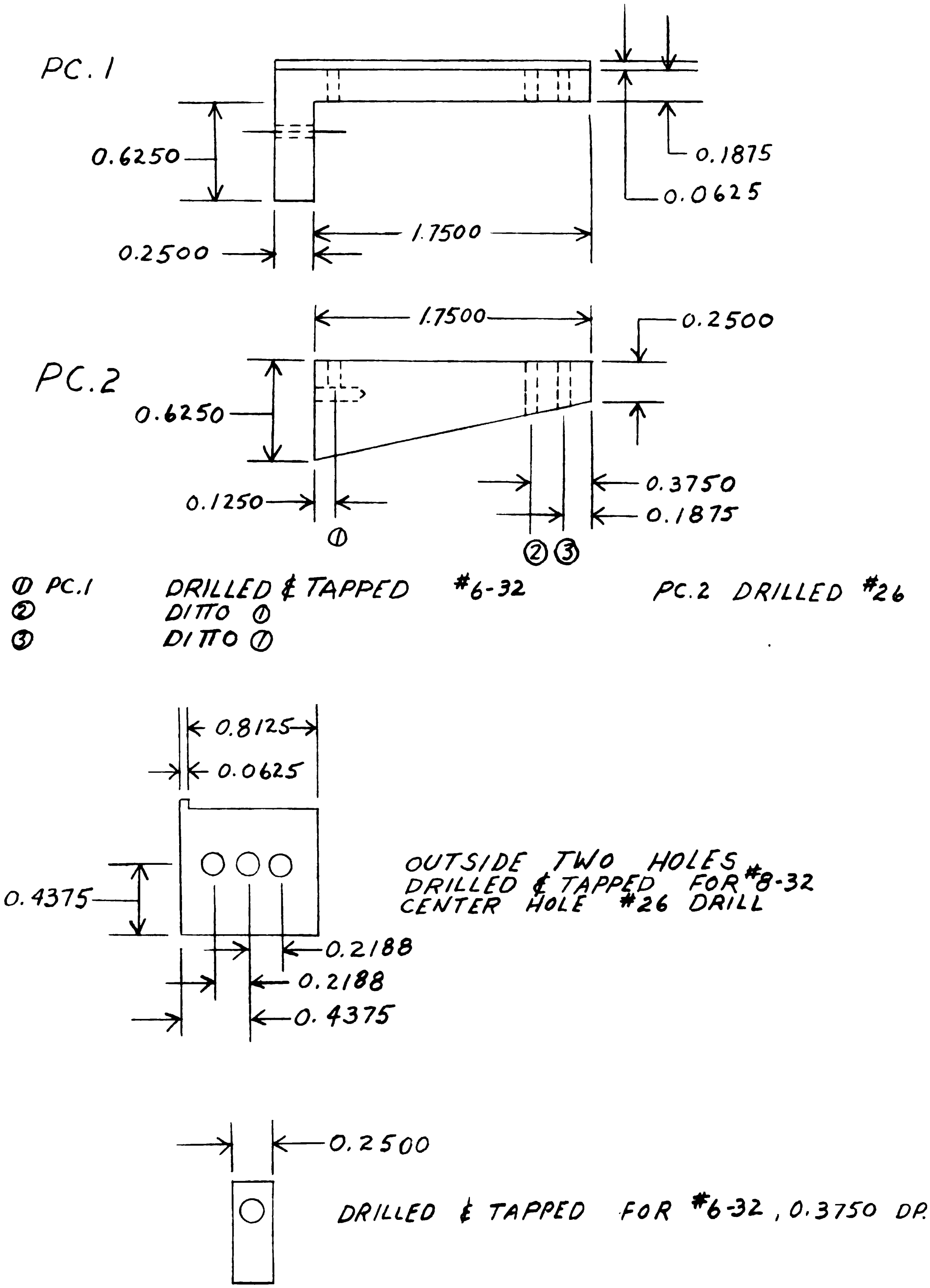
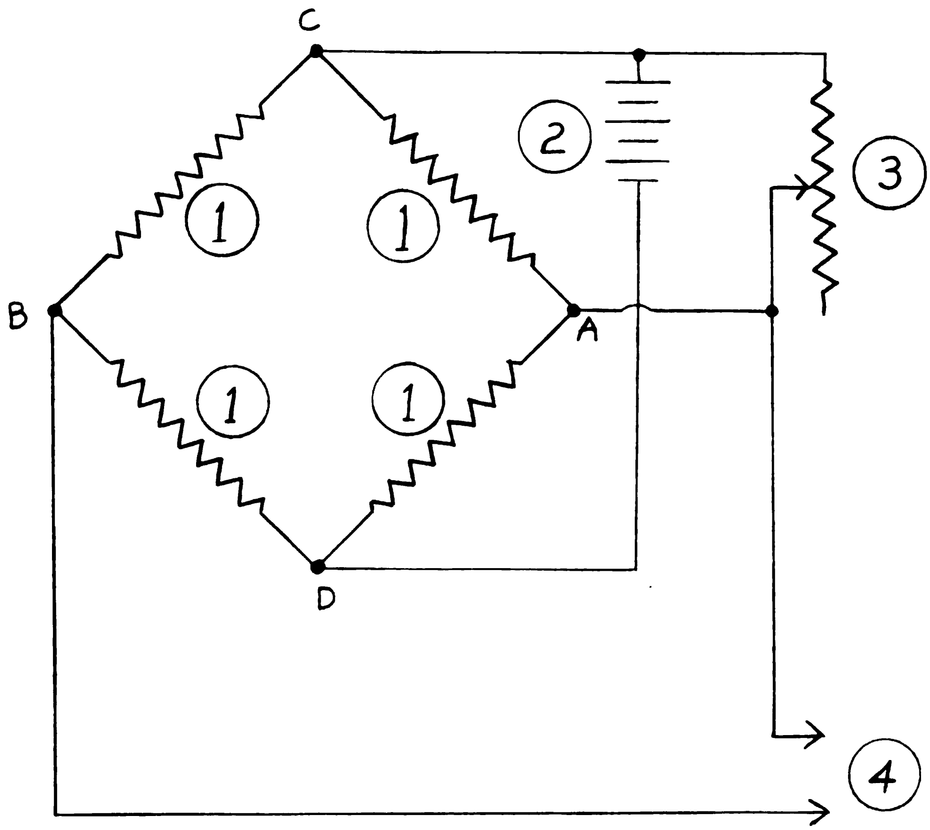


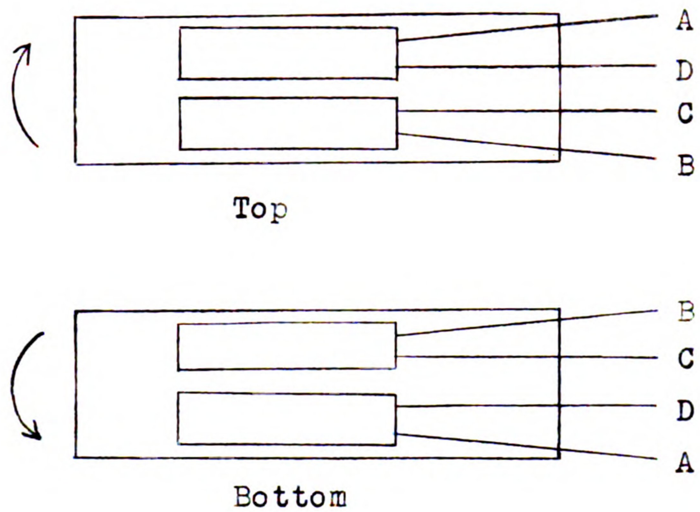
FIGURE 2. BENDING FORCE MEASURING CIRCUIT



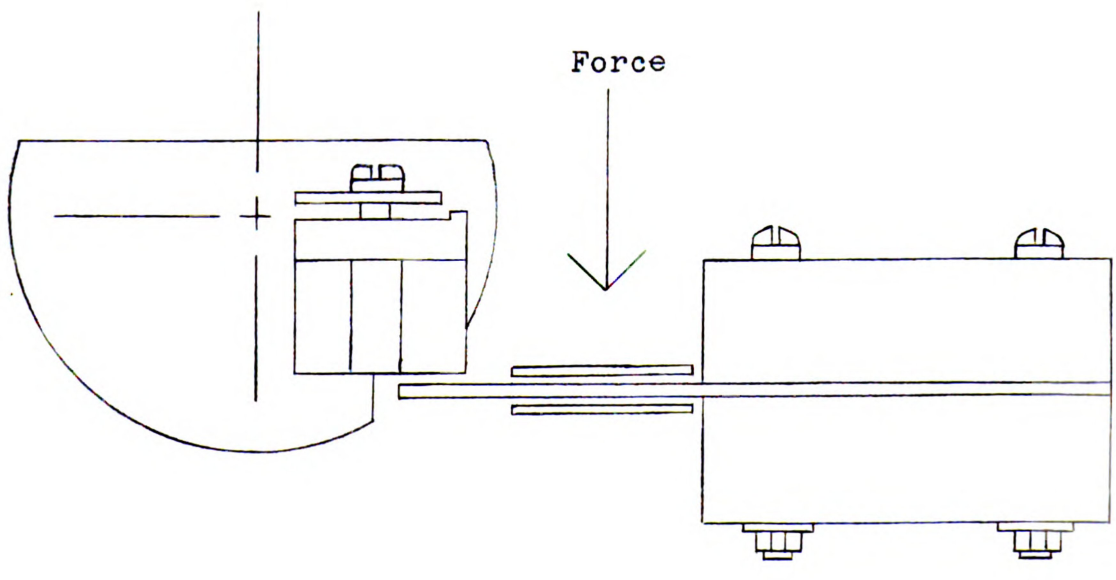
1. Baldwin-Lima-Hamilton SR-4, 350 ohm bakelite strain gage
2. 24 volt dry cell
3. 50,000 ohm micropotentiometer (linear)
41 To amplifier

FIGURE 3. PLACEMENT OF BENDING FORCE MEASURING STRAIN GAGES AND GAGE BEAM

Strain Gage Arrangement on Beam



Strain Gage Beam Mounting on Tester



bakelite strain gages, all of which were active. The gages had a resistance of 350 ohms each. Two gages were mounted on each side on the beam so that as the beam was deflected, two of the gages were in tension and two were compressed.

The signals generated by the gage bridge were fed into a Tektronix Type 122 Low-Level Preamplifier. The amplified signals were fed into the vertical or Y-axis of a Du Mont model 304-A cathode ray oscillograph.

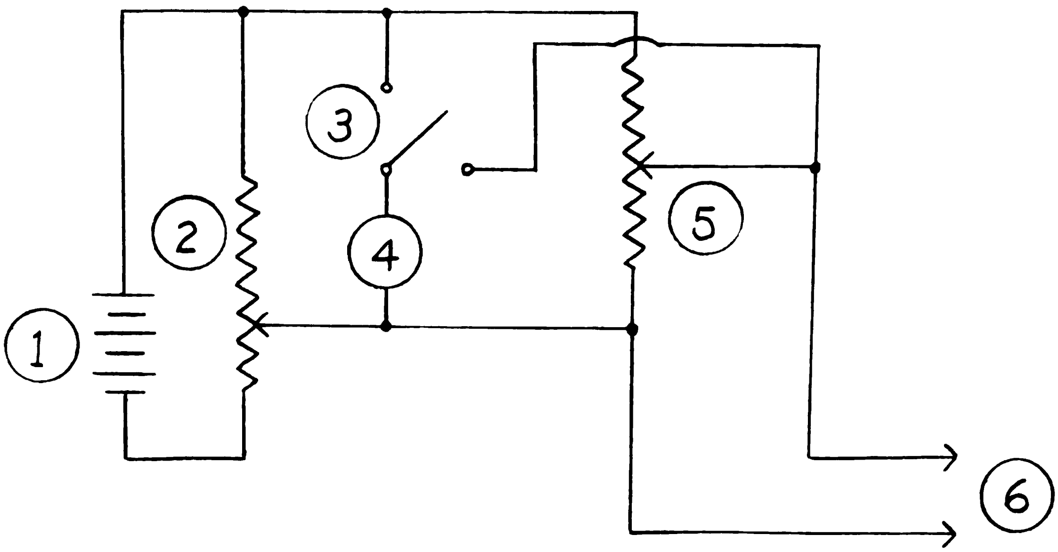
Angular Deflection Measurement

Measurement of angular deflection was accomplished by utilizing a voltage increase caused by 5000 ohm linear micropotentiometer. The potentiometer was geared directly to one of the specimen holder's spur gears. As the spur gear was rotated during the bending of the specimen, the potentiometer divided the voltage output of a 45 volt dry cell. This signal was fed into the horizontal or X-axis of the oscillograph. The distance the oscillograph beam traveled horizontally was controlled by adjusting the X-axis amplitude control until the beam traveled as far across the screen as desired for any given number of degrees deflection.

Drive Mechanism

The motor used to power the device was a Redman, model BL-6, 0.02 horsepower, 3000 rpm, continuous duty motor.

FIGURE 4. ANGULAR DEFLECTION MEASURING CIRCUIT



1. 22½ volt dry cell
2. 1000 ohm potentiometer (linear)
3. Three position non-shorting switch
4. 0-10 volt direct current voltmeter
5. 5000 ohm micropotentiometer (linear)
6. To oscillograph

The remaining sections of the device were stock items produced by the Pic Design Corporation of East Rockaway, Long Island, New York (A). The parts included a magnetic clutch, medel D2-1, rated at 70 ounce-inches output torque and a series of reduction and idler gears. All gears used were 48 pitch, 0.25 inch bore with either 0.1250 inch or 0.1875 inch face width. These gears served to reduce the drive motor rotation to the desired speed for testing and to increase the motor's output torque. By changing the gear relationships within the gear train, operations at rates of 100 to 400 cycles per minute were obtained. For the tests, increments of 50 cycles per minute were utilized.

The primary purpose of the magnetic clutch was to act as an instantaneous coupler between the gear train and the spur gear holding a specimen holder.

Controls

The control system for the device consisted of one A. C. circuit which controlled the magnetic clutch and one D. C. circuit which powered the clutch.

The 110 V.A.C. circuit was designed to operate the drive motor and to actuate a Potter and Brumfield type KB latching relay. The function of the relay was to engage and disengage the magnetic clutch depending upon how it received signals.

(A) For complete parts list refer to Appendix A.

FIGURE 5. SCORELINE TESTER UNIT

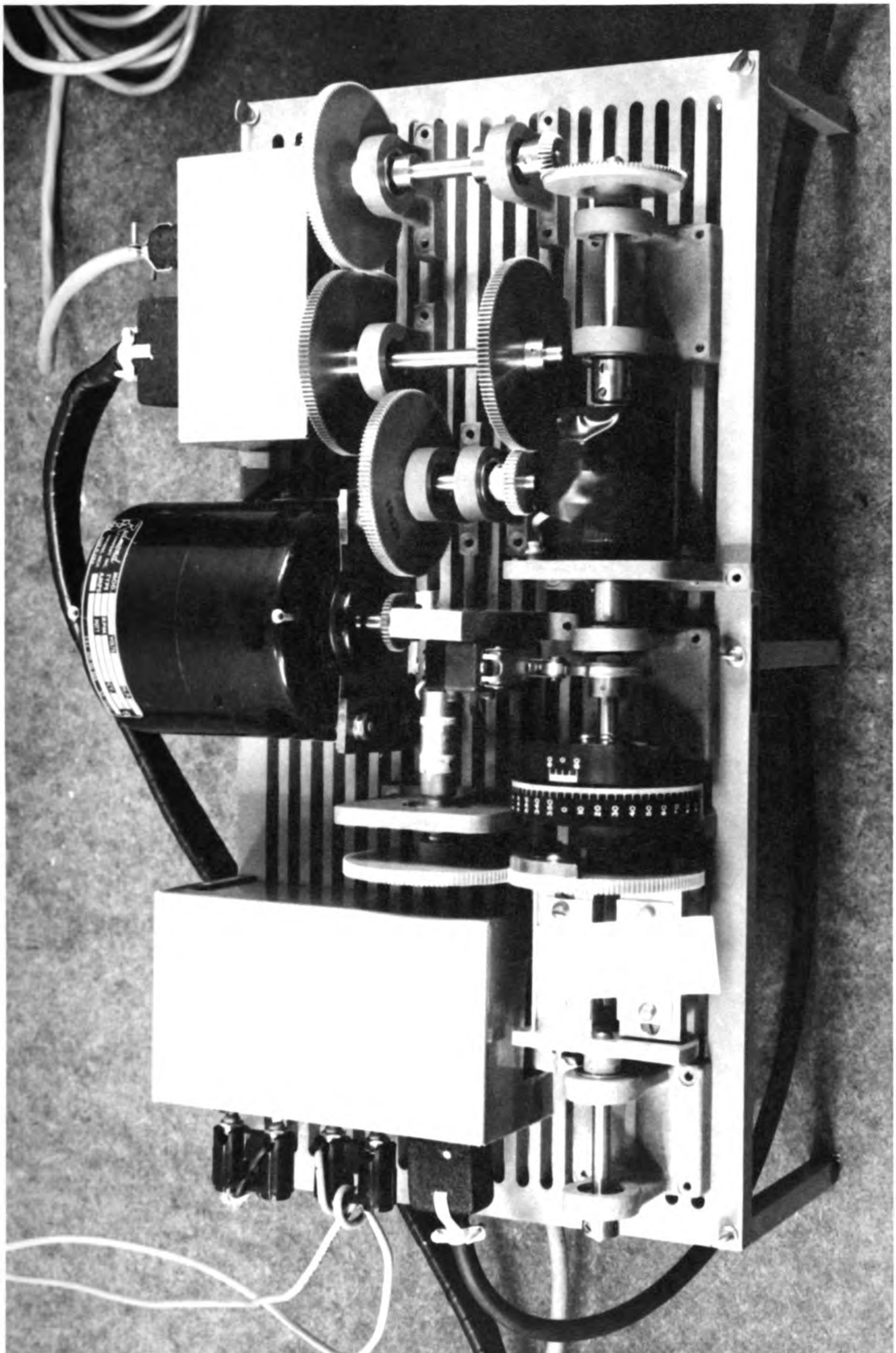
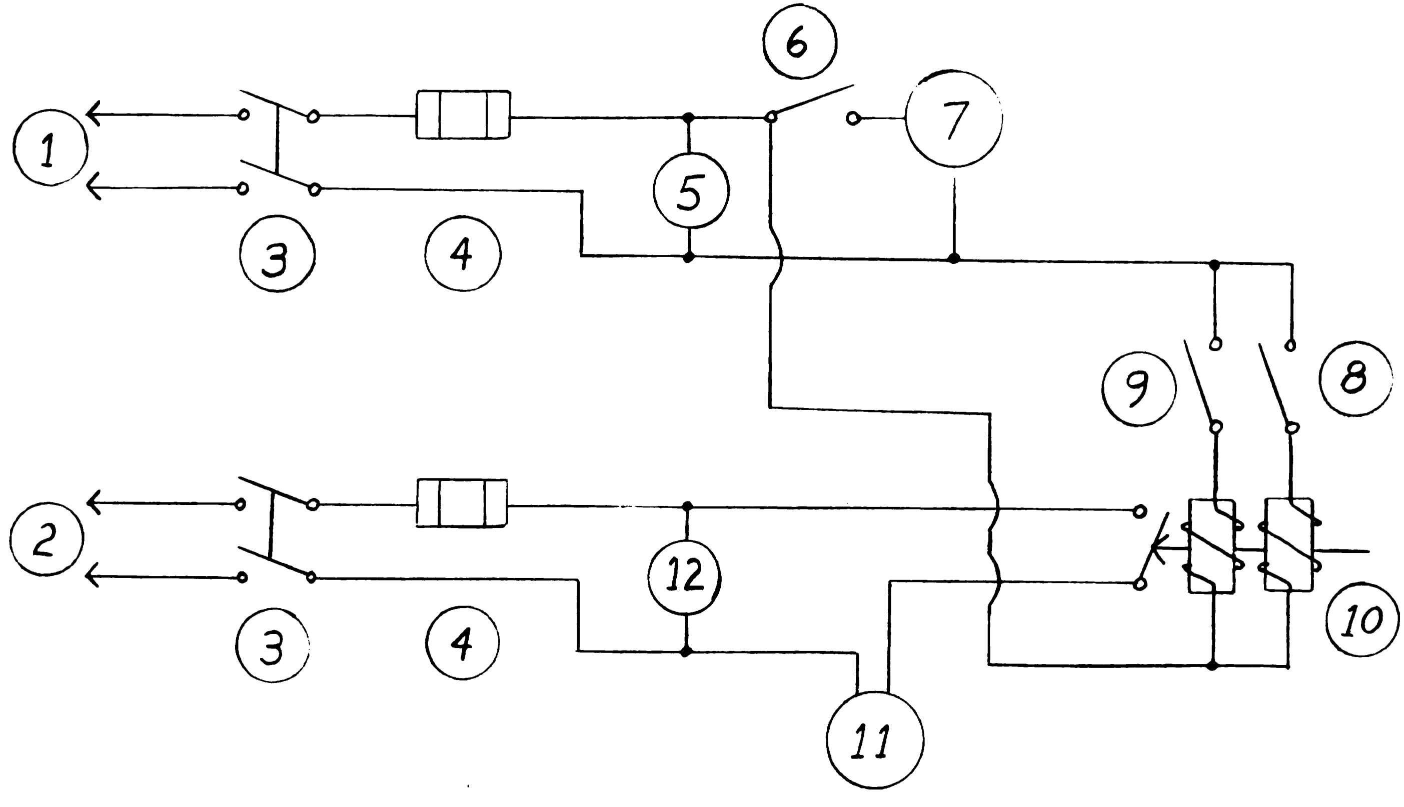


FIGURE 6. SCORELINE TESTER CONTROL CIRCUITS

1. To 110 volts alternating current source
2. To 24-28 volts direct current source
3. Double pole double throw switch
4. Appropriate fuse
5. Neon pilot light (with resistive base)
6. Single pole single throw switch
7. Drive motor
8. Microswitch
9. Single pole momentary contact switch
10. Latching relay
11. Magnetic clutch
12. 32 volt pilot light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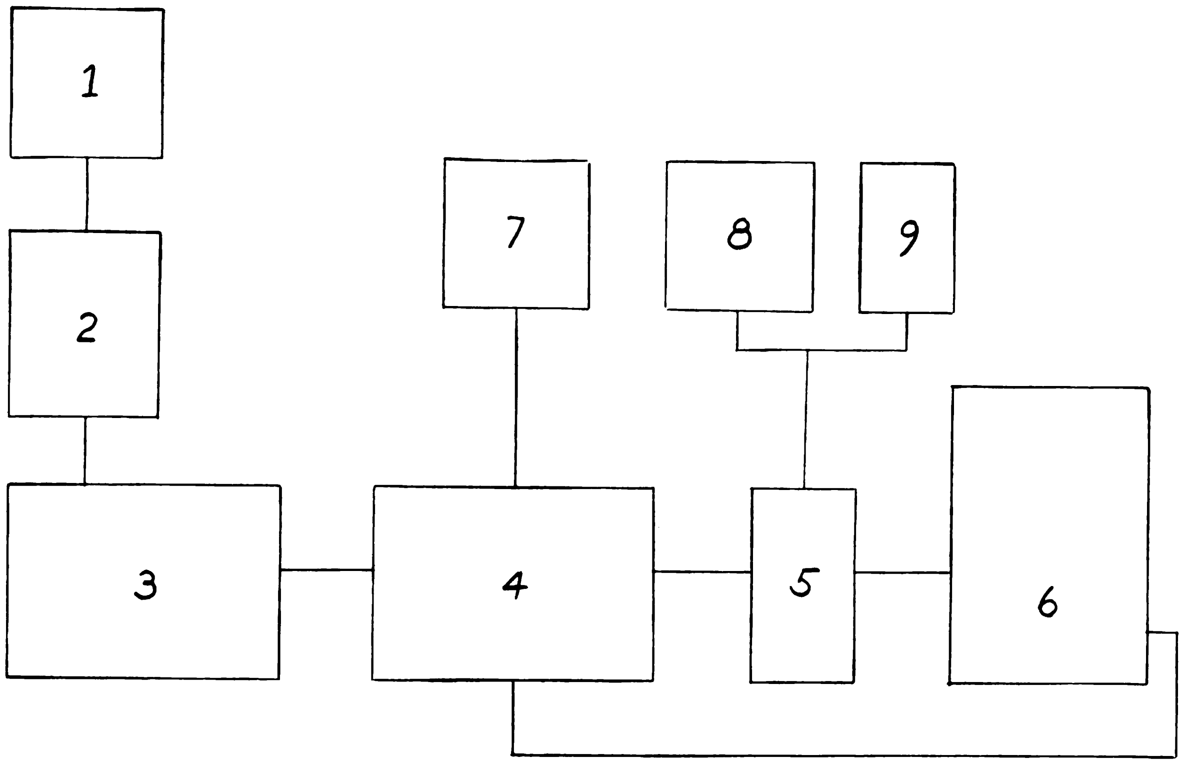
The 26 V.D.C. circuit was used to power the magnetic clutch. The source for the 26 V.D.C. was a laboratory power supply augmented by a Superior model 116 powerstat.

FIGURE 7. BLOCK DIAGRAM OF SCORELINE TESTER COMPONENTS



1. Powerstat
2. D. C. power supply for clutch
3. Control unit
4. Tester
5. Textronix preamplifier
6. Oscilloscope
7. Bridge power supply
8. Preamplifier power supply (6 volts D. C.)
9. Preamplifier power supply (45 volts D. C.)

FIGURE 8. COMPLETE SCORELINE TESTER ASSEMBLY

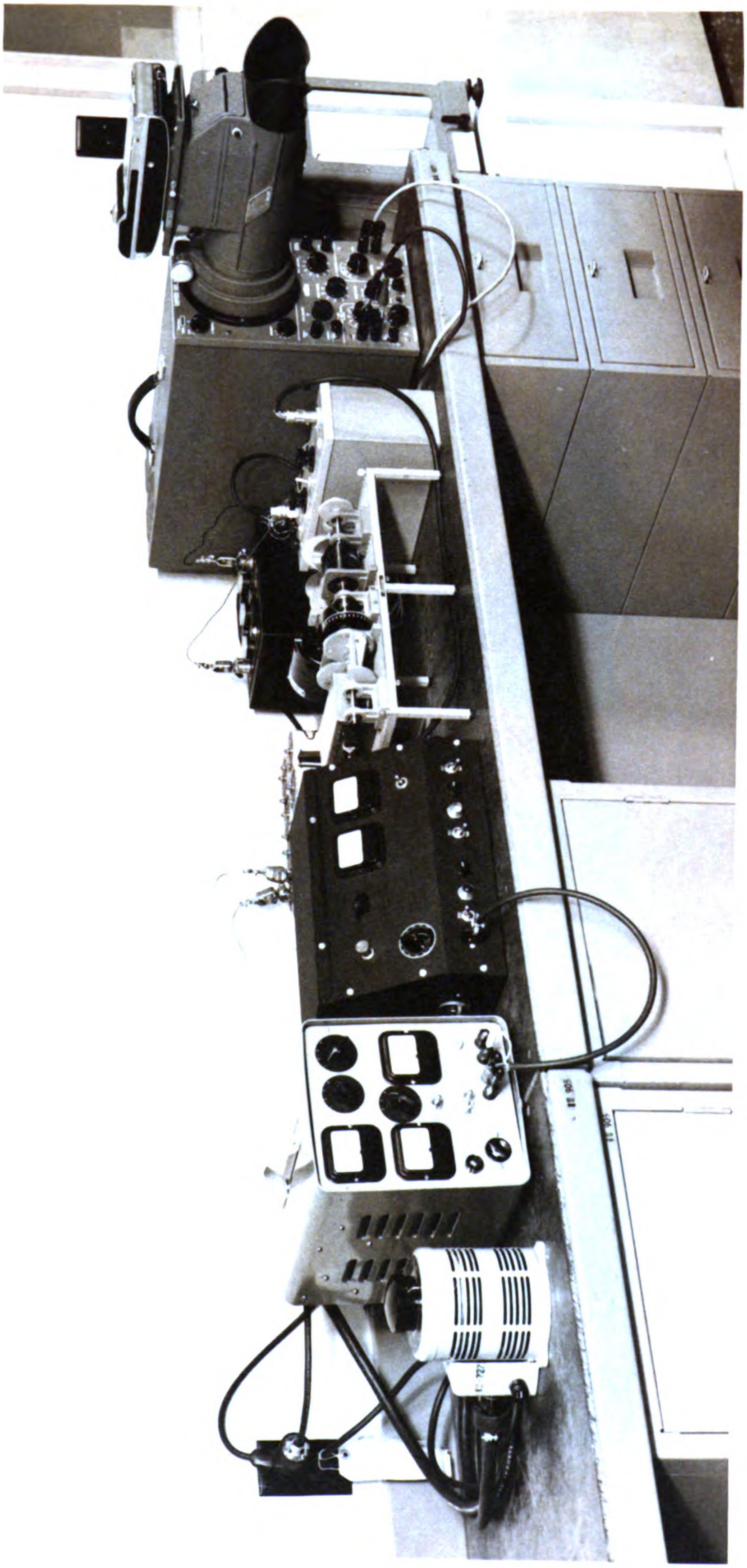
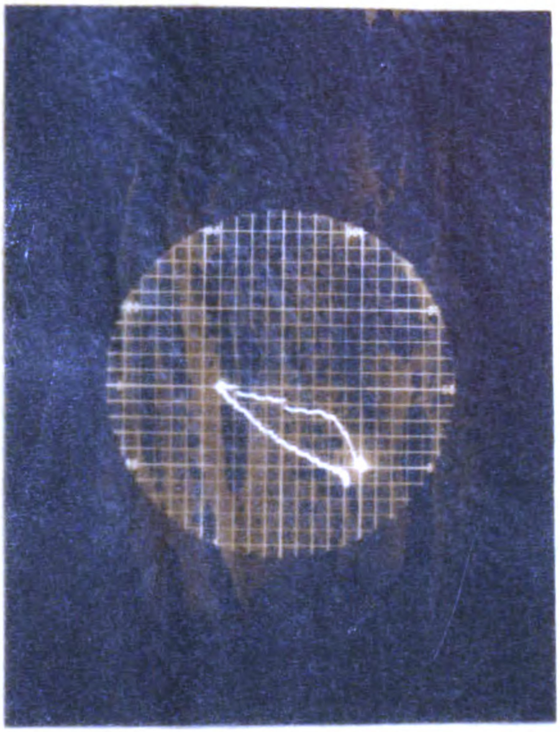
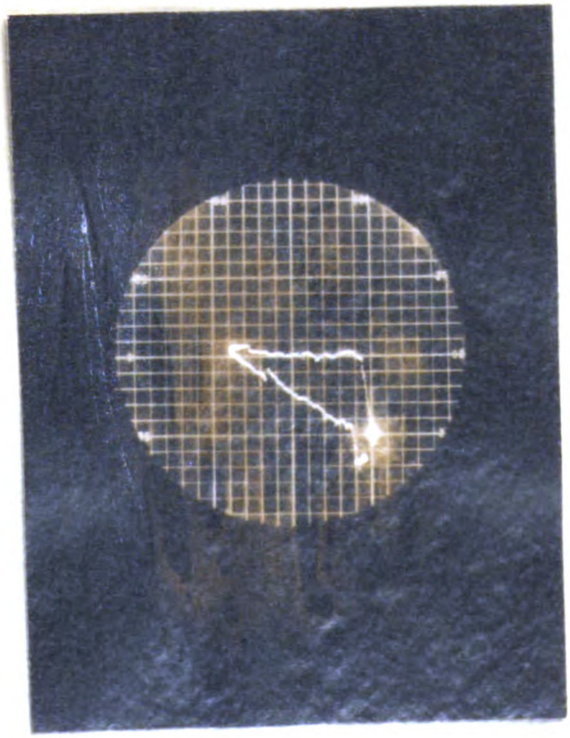


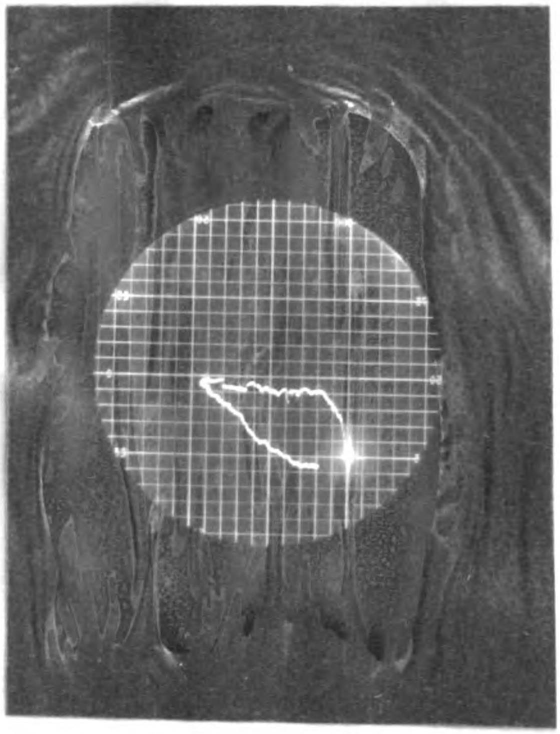
FIGURE 9. TYPICAL OSCILLOGRAPH TRACES



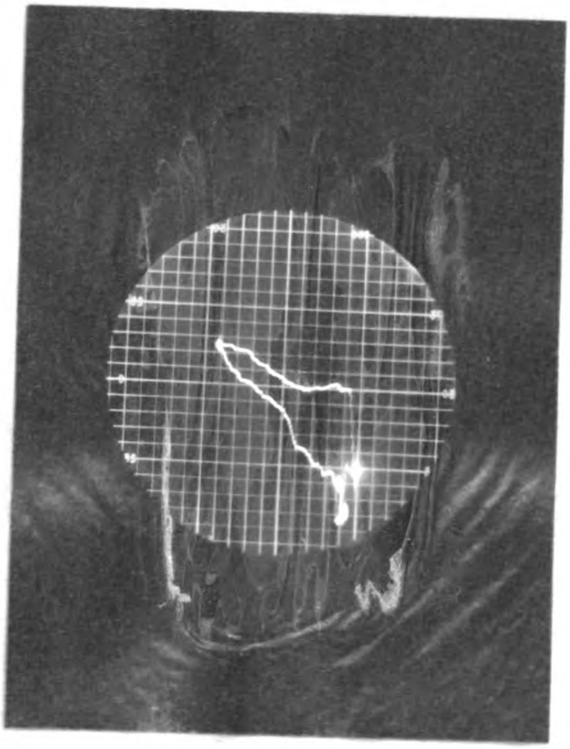
MANICO Makeready Machine Direction



MANICO Makeready Cross Direction



Engraved Makeready Machine Direction



Engraved Makeready Cross Direction

EXPERIMENTAL PROCEDURE

Specimen Material

The test specimens used were taken from materials furnished by the Carton and Container Division of General Foods Corporation. The materials were selected at random from materials used in production.

Specimens were cut from blanks constructed of 0.034 inch thick bending chipboard with a 60 pound per 1000 square feet printed liner wax-laminated to it.

Specimen Machine Direction

The direction of the scoreline in relation to the machine or grain direction of the board was considered by using an equal number of specimens having scorelines parallel to the grain direction and specimens having scorelines perpendicular to the grain direction.

The widths of the femal dies were greater for scorelines which were across the grain direction. This was done in an effort to reduce the normally high resistance to bending that cross direction scorelines generally have.

Specimen Scorelines

One-half of the specimens were scored on MANICO female dies and one-half on engraved steel makeready plates.

The scorelines produced on MANICO dies had widths of 0.084 inch (No. 6 MANICO) for machine direction scores and 0.099 inch (No. 8 MANICO) for cross direction scores.

The scoreline depth into the board was 0.031 inch.

The scorelines produced on the engraved steel makeready plates had widths of 0.102 inch for machine direction scores and 0.110 inch for cross direction scores. The scoreline depth into the board was 0.034 inch.

The scoring rules used for all specimens were 0.042 inch wide. All other variables believed connected with scoring were held constant.

Specimen Conditioning

The moisture content of the specimens used was controlled by storing the specimens in an atmosphere of $50 \pm 2\%$ relative humidity and $73 \pm 2^{\circ}F$ for a period of 96 hours prior to testing.

Testing Speed

The speed of testing was varied from 100 cycles per minute to 400 cycles per minute by 50 cycles per minute increments. This range of testing speeds was selected because it approximates the ranges of today's packaging lines. The higher speeds were given equal weight with the lower and middle range speeds because rates of 400 units per minute are now in the experimental stage.

Specimen Sample Size

The number of variables involved in the tests were purposely kept to a minimum. The three variables used were the two types of makereadies, the seven testing speeds, and the two directions of scorelines in relation to the machine direction of the board.

These variables resulted in 28 possible combinations. In order to facilitate testing, a sample size of five was selected. This gave a total sample size of 140 specimens.

ANALYSIS OF DATA

As stated previously, the tests were conducted to demonstrate the testing device. Therefore, the following tables are presented only to illustrate the ability of the machine to show changes in the force required to bend a scoreline as a result of changes in the scoring variables.

The values of the bending force, break angle, and springback represent an average value of the five specimen sample (A). All specimens were bent to 90°. The angle of 90° was used because this is the angle through which folding box scorelines are bent when the boxes are set up and sealed. All values were obtained from photographs of the oscillograph traces.

The values obtained for bending force were not in units of force. They were relative values used to illustrate differences in the force necessary to bend different specimens.

The values of bending force were seen to follow two general patterns. The first pattern was a sharp increase in force up to the break angle after which the values dropped, leveled off, or continued to rise gradually. These values represented scorelines perpendicular to the the grain direction of the board. The second pattern was

(A) Break angle refers to that angle at which the initial bend occurred. Springback refers to that angle which the specimen made after the specimen had been bent and released.

a gradual increase to the break angle after which the values leveled off or continued to rise. This pattern was typical of scorelines running parallel to the grain direction.

The break angle values for scorelines running perpendicular to the grain direction of the board were generally lower than for grain direction scorelines. This was due to the fibers actually breaking when cross direction scorelines were bent. In grain direction scorelines, the fibers pull apart giving a gradual failure.

Springback values for scorelines running parallel to the grain direction of the board were generally higher than for cross direction scorelines. This too is due to the fibers rupturing in cross direction scorelines.

TABLE I

AVERAGE VALUES OF BENDING FORCE OF SPECIMENS TESTED AT 100 CYCLES PER MINUTE*

	MANICO MAKEREADY		ENGRAVED MAKEREADY	
DEFLECTION	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
5	0.5	2.3	0.5	4.0
10	2.0	4.9	2.8	7.1
15	2.5	6.0	3.8	7.3
20	3.1	5.9	4.8	6.7
25	3.1	5.6	5.1	6.6
30	3.3	5.6	4.9	6.4
35	3.5	5.5	4.9	6.4
40	3.7	5.7	4.9	6.3
45	3.8	5.9	4.8	6.5
50	3.9	6.0	4.8	6.5
55	4.0	6.2	4.8	6.7
60	4.1	6.2	4.7	6.7
65	4.2	6.2	4.8	6.8
70	4.2	6.2	4.7	6.8
75	4.3	6.5	4.7	6.8
80	4.3	6.6	4.8	6.8
85	4.3	6.6	4.8	6.8
90	4.4	6.7	4.8	6.7

*Values of bending force are relative. The units used represent the distance the force signal traveled on the oscilloscope screen.

TABLE II

AVERAGE VALUES OF BENDING FORCE OF SPECIMENS TESTED AT 150 CYCLES PER MINUTE*

	MANICO MAKEREADY		ENGRAVED MAKEREADY	
DEFLECTION	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
5	1.0	1.3	0.9	3.3
10	3.0	5.0	2.3	6.8
15	4.3	5.4	3.2	7.5
20	4.8	5.5	3.5	7.3
25	5.0	5.5	3.7	7.0
30	5.0	5.5	3.8	7.0
35	5.0	5.8	3.8	7.1
40	5.0	6.0	3.8	7.3
45	5.1	6.1	4.0	7.5
50	5.1	6.3	4.1	7.6
55	5.2	6.4	4.2	7.8
60	5.2	6.5	4.2	8.0
65	5.4	6.7	4.2	8.3
70	5.6	6.8	4.4	8.5
75	5.8	6.9	4.4	8.8
80	5.9	7.0	4.5	9.0
85	6.1	7.1	4.6	9.3
90	6.4	7.2	4.6	9.5

*Values of bending force are relative. The units used represent the distance the force signal traveled on the oscillograph screen.

TABLE III

AVERAGE VALUES OF BENDING FORCE OF SPECIMENS TESTED AT 200 CYCLES PER MINUTE*

DEFLECTION	MANICO MAKEREADY WITH GRAIN	MANICO MAKEREADY ACROSS GRAIN	ENGRAVED MAKEREADY WITH GRAIN	ENGRAVED MAKEREADY ACROSS GRAIN
5	1.2	2.7	0.8	3.0
10	2.4	5.8	2.3	6.4
15	3.6	6.1	4.5	7.4
20	3.9	6.1	5.4	7.1
25	4.1	6.0	5.4	7.0
30	4.1	5.9	5.4	7.0
35	4.2	5.9	5.4	7.0
40	4.4	6.2	5.6	7.0
45	4.5	6.2	5.6	7.2
50	4.6	6.5	5.6	7.4
55	4.7	6.8	5.7	7.4
60	4.9	7.0	5.8	7.6
65	5.1	7.2	5.9	7.8
70	5.2	7.5	6.0	8.0
75	5.3	7.8	6.1	8.1
80	5.5	8.1	6.1	8.1
85	5.6	8.4	6.2	8.1
90	5.7	8.7	6.3	8.1

*Values of bending force are relative. The units used represent the distance the force signal traveled on the oscillograph screen.

TABLE IV

AVERAGE VALUES OF BENDING FORCE OF SPECIMENS TESTED AT 250 CYCLES PER MINUTE*

DEFLECTION	MANICO MAKEREADY		ENGRAVED MAKEREADY	
	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
5	1.7	4.3	1.8	5.2
10	3.2	6.3	3.8	7.2
15	3.9	6.5	5.3	7.2
20	4.4	6.5	5.3	7.2
25	4.7	6.6	5.3	6.9
30	4.9	6.6	5.3	6.8
35	5.0	6.6	5.3	6.9
40	5.0	6.8	5.3	7.0
45	5.1	6.8	5.3	7.2
50	5.1	6.8	5.3	7.4
55	5.2	6.7	5.3	7.6
60	5.2	6.7	5.3	7.6
65	5.2	6.7	5.5	7.7
70	5.3	6.7	5.5	7.7
75	5.3	6.8	5.6	7.8
80	5.3	7.0	5.7	7.8
85	5.4	7.1	5.7	7.8
90	5.5	7.2	5.8	7.9

*Values of bending force are relative. The units used represent the distance the force signal traveled on the oscillograph screen.

TABLE V

AVERAGE VALUES OF BENDING FORCE OF SPECIMENS TESTED AT 300 CYCLES PER MINUTE*

	MANICO MAKEREADY		ENGRAVED MAKEREADY	
DEFLECTION	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
5	1.4	4.0	1.3	5.3
10	2.5	5.7	3.6	7.8
15	3.1	5.7	4.7	7.9
20	3.3	5.7	5.3	8.0
25	3.5	5.8	5.5	8.0
30	3.8	5.9	5.7	8.1
35	3.8	6.1	5.8	8.1
40	4.0	6.3	5.9	8.2
45	4.0	6.4	5.9	8.3
50	4.1	6.5	6.0	8.4
55	4.2	6.6	6.1	8.6
60	4.2	6.6	6.1	8.9
65	4.4	6.8	6.1	9.1
70	4.6	6.9	6.2	9.4
75	4.8	7.1	6.4	9.6
80	5.0	7.2	6.6	9.9
85	5.6	7.3	6.7	10.1
90	5.8	7.3	6.9	10.3

*Values of bending force are relative. The units used represent the distance the force signal traveled on the oscillograph screen.

TABLE VI

AVERAGE VALUES OF BENDING FORCE OF SPECIMENS TESTED AT 350 CYCLES PER MINUTE*

	MANICO MAKEREADY		ENGRAVED MAKEREADY	
DEFLECTION	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
5	0.9	6.1	1.5	5.3
10	3.0	6.5	3.8	7.6
15	4.0	6.5	4.6	8.1
20	4.5	6.5	5.0	8.3
25	4.9	6.7	5.4	8.4
30	5.3	6.8	5.4	8.7
35	5.6	6.9	5.5	8.8
40	5.8	7.1	5.7	8.9
45	5.9	7.2	5.9	9.1
50	6.0	7.4	6.0	9.3
55	6.1	7.5	6.2	9.5
60	6.3	7.7	6.3	9.7
65	6.4	7.8	6.6	10.0
70	6.7	8.3	6.8	10.4
75	7.2	8.8	7.6	10.8
80	7.8	9.0	8.5	11.6
85	8.2	9.4	9.5	12.2
90	8.6	9.5	11.0	12.8

*Values of bending force are relative. The units used represent the distance the force signal traveled on the oscillograph screen.

TABLE VII

AVERAGE VALUES OF BENDING FORCE OF SPECIMENS TESTED AT 400 CYCLES PER MINUTE*

	MANICO MAKEREADY		ENGRAVED MAKEREADY	
DEFLECTION	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
5	1.5	3.0	3.0	4.8
10	4.5	6.2	5.0	7.8
15	5.3	7.0	5.7	8.2
20	5.6	7.1	6.0	8.2
25	5.8	7.2	6.5	8.3
30	6.1	7.3	6.8	8.3
35	6.1	7.5	6.8	8.3
40	6.4	7.6	6.7	8.3
45	6.5	7.7	6.8	8.3
50	6.5	7.8	6.8	8.4
55	6.7	7.9	6.9	8.7
60	6.8	8.0	7.0	9.1
65	7.4	8.2	7.2	9.6
70	8.0	8.3	7.5	10.0
75	9.1	8.8	8.0	10.5
80	10.3	9.0	8.3	11.0
85	11.7	9.6	9.1	11.5
90	12.7	10.0	9.8	12.0

*Values of bending force are relative. The units used represent the distance the force signal traveled on the oscillograph screen.

TABLE VIII

AVERAGE VALUES OF THE BREAKING ANGLE*

	MANICO MAKEREADY		ENGRAVED MAKEREADY	
TESTING SPEED**	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
100	13	15	18	12
150	20	11	17	12.5
200	17	14	18	13
250	17	13	17	10
300	13	9	18	9
350	18	8	15	13
400	13	15	11	9

* Break angle refers to that angle at which the initial bend occurs. All values are in degrees.

** Cycles per minute.

TABLE IX

AVERAGE VALUES OF SPRINGBACK*

	MANICO MAKEREADY		ENGRAVED MAKEREADY	
TESTING SPEED**	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
100	32	17	17	19
150	25	23	26	15
200	25	23	25	26
250	32	32	30	18
300	28	27	23	22
350	22	24	20	19
400	18	18	10	25

* All values are in degrees.

**Cycles per minute.

TABLE X

AVERAGE VALUES OF BREAKING FORCE*

	MANICO MAKEREADY		ENGRAVED MAKEREADY	
TESTING SPEED**	WITH GRAIN	ACROSS GRAIN	WITH GRAIN	ACROSS GRAIN
100	2.5	6.0	4.6	7.3
150	4.8	5.3	5.3	7.4
200	3.8	6.1	5.3	7.3
250	4.1	6.5	5.3	7.2
300	3.9	5.9	5.1	7.8
350	4.8	6.4	4.6	8.1
400	5.1	7.0	5.2	7.8

* Breaking force refers to the value of the bending force at the break angle.

**Cycles per minute.

CONCLUSIONS

The tests indicated that the tester is capable of illustrating scoreline variations in three areas.

The direction of the scoreline in relation to the grain direction of the board was the most flexible variable. In all cases, the force required to bend scorelines parallel to the grain direction was considerably less than the force required to bend scorelines perpendicular to the grain direction. The breaking angle was generally greater for with-grain scorelines than for across-grain scorelines. Springback was generally less for with-grain scorelines than for across-grain scorelines.

The variation of bending force as a function of makeready width and depth of scoreline was conclusively illustrated. There was evidence that wide, shallow scorelines are somewhat more resistant to bending than narrow, deep scorelines.

Variation in bending force, as a function of testing speed, was shown by an increase in bending force required as testing speed increased. The force required to break the scorelines was greatly increased as the testing speed increased. This would mean that as testing speeds increase, the scorelines should be narrower and deeper if it is desirable to have all the specimens perform about the same.

RECOMMENDATIONS FOR FUTURE DEVELOPMENT OF THE SCORELINE TESTER

Replacement of the gear train by a variable speed motor or by a transmission or a variable speed reducer unit would decrease vibration, allow quicker changes in the testing speed, and greatly reduce operation noise.

In order to test specimens at rates above 400 cycles per minute, the magnetic clutch used should be replaced with a clutch-brake combination. This would allow the torque to be applied through any angle and then the rotation stopped at any angle.

The mass of the dynamic specimen holder assembly should be reduced as much as possible. The smaller the holder assembly mass, the less inertia it will present when the specimens are being stopped at the test angle. The present holder assembly has a tendency to ride past the test angle.

Some other method of measuring angular deflection may be desirable. The turning friction of the micropotentiometer may cause springback values to be too high.

Coupling the oscillograph camera into the cycling circuit so that there is no danger of obtaining an incomplete trace record may be desirable. Employing a timer to hold the shutter open is another solution. The main danger is not obtaining accurate springback measurements.

Calibrating the strain gage bridge in units of ounce-inches or grams-millimeters would allow actual physical unit values to be obtained. These values may be of greater interest than relative values.

These recommendations are made on the basis of experience and observations. They were not incorporated into the tester because the time and materials were not available.

REFERENCES

1. Hine, D. J., "The Creasing Properties of Carton Board, Part III; A Dynamic Crease Folding Tester.", The Printing, Packaging, and Allied Trades Research Association Packaging Laboratory Report No. 9, January, 1958.

2. Kernan, J. M. and Lewis, R. L., "The Ohio Boxboard Score Bend Tester.", Tappi, March, 1958.

3. Lewis, R. L. and Eckhart, C. G., "End-of-Machine Control Tests for Boxboard Printability and Score-ability.", Tappi, October, 1956.

4. Schulz, G. L., The Stiffness of Folding Boxboard Scores as a Function of Scoring Rule, Makeready, Depth of Penetration, and Mositure Content., M.S. Thesis, Michigan State University, June 1958.

5. Teeple, J. H. and Noll, R. G., "The Marathon Score Test.", Tappi, February, 1959.

APPENDIX A. OPERATION OF THE SCORELINE TESTER

1.) Select the correct gear relationships for the desired testing speed from the gear chart. Use care to assure proper gear alignment when adjusting gears.

2.) Refer to circuit diagrams for correct voltages and currents. OVERLOADING OF DIRECT CURRENT CIRCUIT WILL CAUSE COMPONENT FAILURE.

3.) Adjust the microswitch activating cam to obtain the desired deflection. This must be done by trial due to the inertia of the moving specimen holder assembly.

4.) Selection of oscillograph and preamplifier settings are dependent on the material being tested. The most favorable settings must be obtained by trial.

5.) Shim stock or other suitable rigid filler must be used to raise the center of the specimen's thickness so that it passes through the spur gear axis.

6.) If photographic records are going to be taken, select proper camera adjustments and oscillograph intensity settings.

7.) Place specimen in holders. Do not tighten clamps down excessively tight.

8.) Open camera shutter and press cycle switch. DO NOT HOLD CYCLE SWITCH BUTTON DOWN. Close camera shutter as soon as specimen has sprung back.

9.) Do not leave oscillograph intensity on a high setting when developing pictures or changing drive gear relationships.

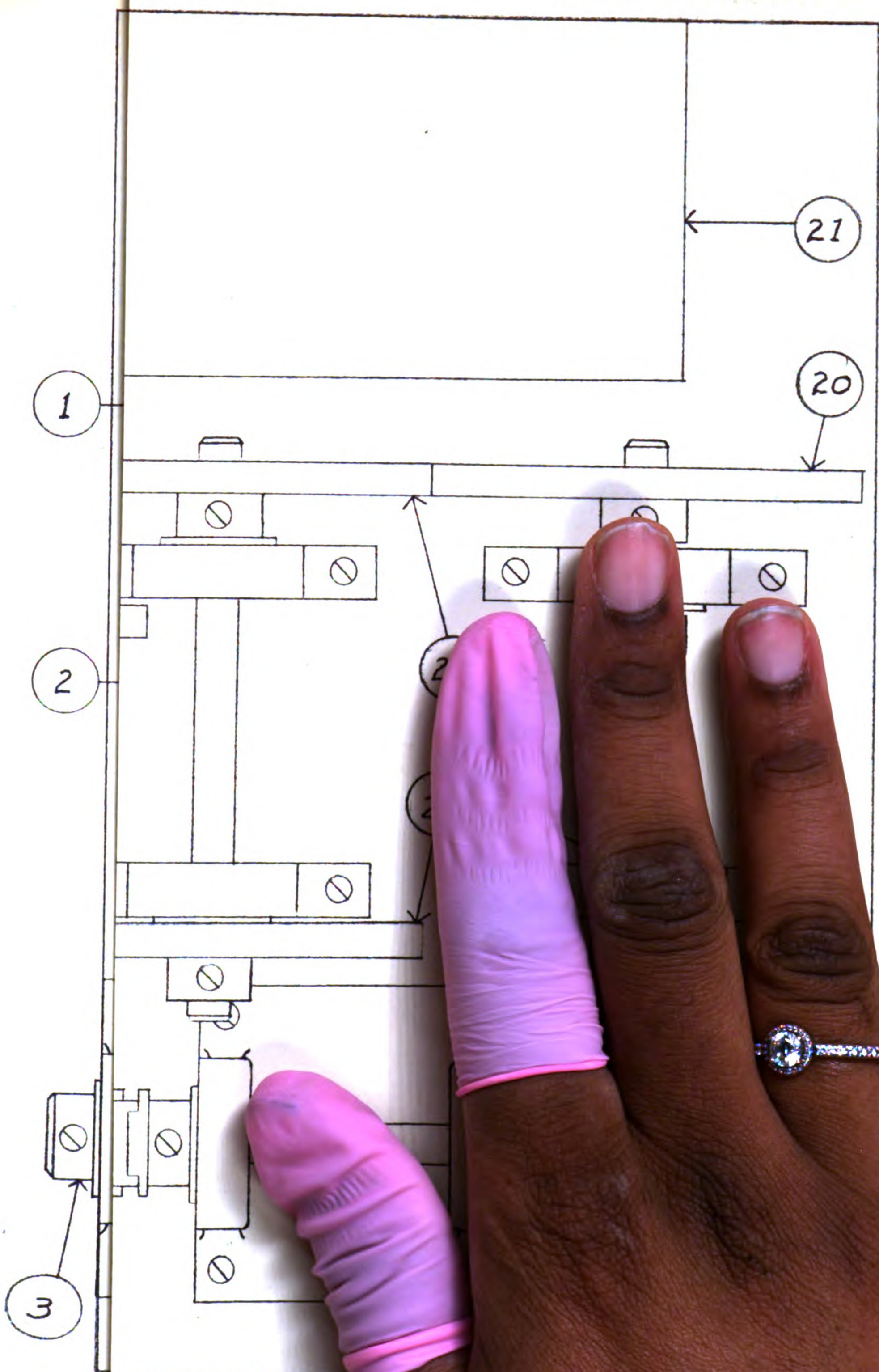
10.) For additional specimens, repeat steps seven and eight. Frequent checks on the position of the oscillograph beam's position whould be made to assure repeatibility of traces.

TESTING SPEED GEAR SELECTION CHART

MOTOR GEAR*	REDUCTION GEAR	OPERATING SPEED
36	40	100
72	30	150
72	40	200
72	50	250
72	60	300
72	70	350
72	80	400
72	90	450
72	100	500
72	110	550
72	120	600

*Gear values indicate teeth number.

FIGURE 10. FULL SCALE DRAWING
OF THE SCORELINE TESTER UNIT


21
20
1
2
3

Unless otherwise stated, all parts used in the construction of the Scoreline Tester Unit were manufactured by the Pic Design Corporation, East Rockaway, Long Island, New York. The part numbers listed were taken from the Pic Master Catalog number 21.

1. Bud CU-2106A Minibox
2. Strain Gage Beam (Figure 3.)
3. C1-3 Set Screw Collar
4. A3 Series Shaft
5. R5-12 Double Shaft Hanger
6. E2-7 Flanged Ball Bearing
7. BQ2-20 Gear Blank
8. Specimen Holders (Figure 1.)
9. G8-120 Spur Gear
10. R1-10 Universal Shaft Hanger
11. M2-21 Engraved Drum Dial
12. P1-3 Adjustable Cam Assembly
13. C1-3 Set Screw Collar
14. T7-3 Oldham Coupling
15. S1-3 Component Mounting Hanger
16. Assembly consisting of one each:

    L2-2 Cleat

    Y6-4 Washer

    Y1-4-V Screw

17. DZ-1 Magnetic Clutch

18., 19. N3-3 Miter and Bevel Gear Set

20. G8-120 Spur Gear

21. Bud CU-2102A Minibox
22. G7-120 Spur Gear
23. A3 Series Shafts
24. G7-120 Spur Gear
25. This gear is changed to create desired testing speed.
26. G8-120 Spur Gear
27. This gear is changed to create desired testing speed.
28. AO-1T Cam Switch Hanger
29. Type 2HBT23-1 Microswitch
30. IRC 5000 ohm, 10 Turn Micropotentiometer
31. Redman Model BL-6, 0.02 h.p.
32. S1-6 Component Mounting Hanger
33. G8-120 Spur Gear

Base consists of a BB2, 8" x 16" Breadboard Plate.

APPENDIX B. SCORING VARIABLES

Calipher of board

Board material

Grain direction

Moisture content

Width male

Width female

Male corners

Female corners

Depth of penetration

Motion of scoring machine

Speed of scoring machine

Pressure of scoring machine

APPENDIX C. BENDING FORCE - ANGULAR DEFLECTION GRAPHS

GRAPH I

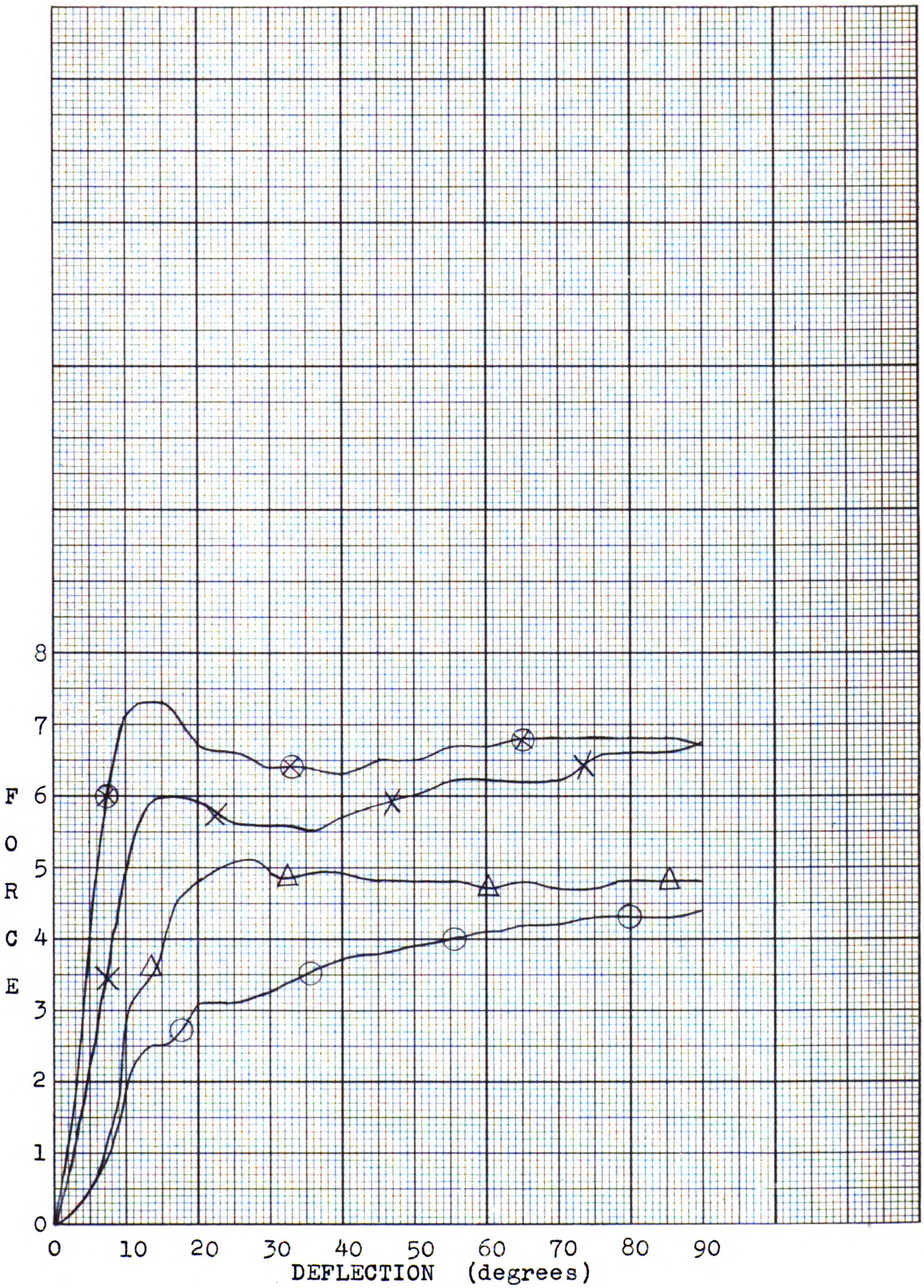
Bending force - angular deflection graph for specimens tested at 100 cycles per minute.

-⊖- MANICO makeready machine direction

-×- MANICO makeready cross direction

-△- Engraved makeready machine direction

-⊗- Engraved makeready cross direction


8
7
6
5
4
3
2
1
0
F
O
R
C
E
0
10
20
30
40
50
60
70
80
90
DEFLECTION (degrees)

GRAPH II

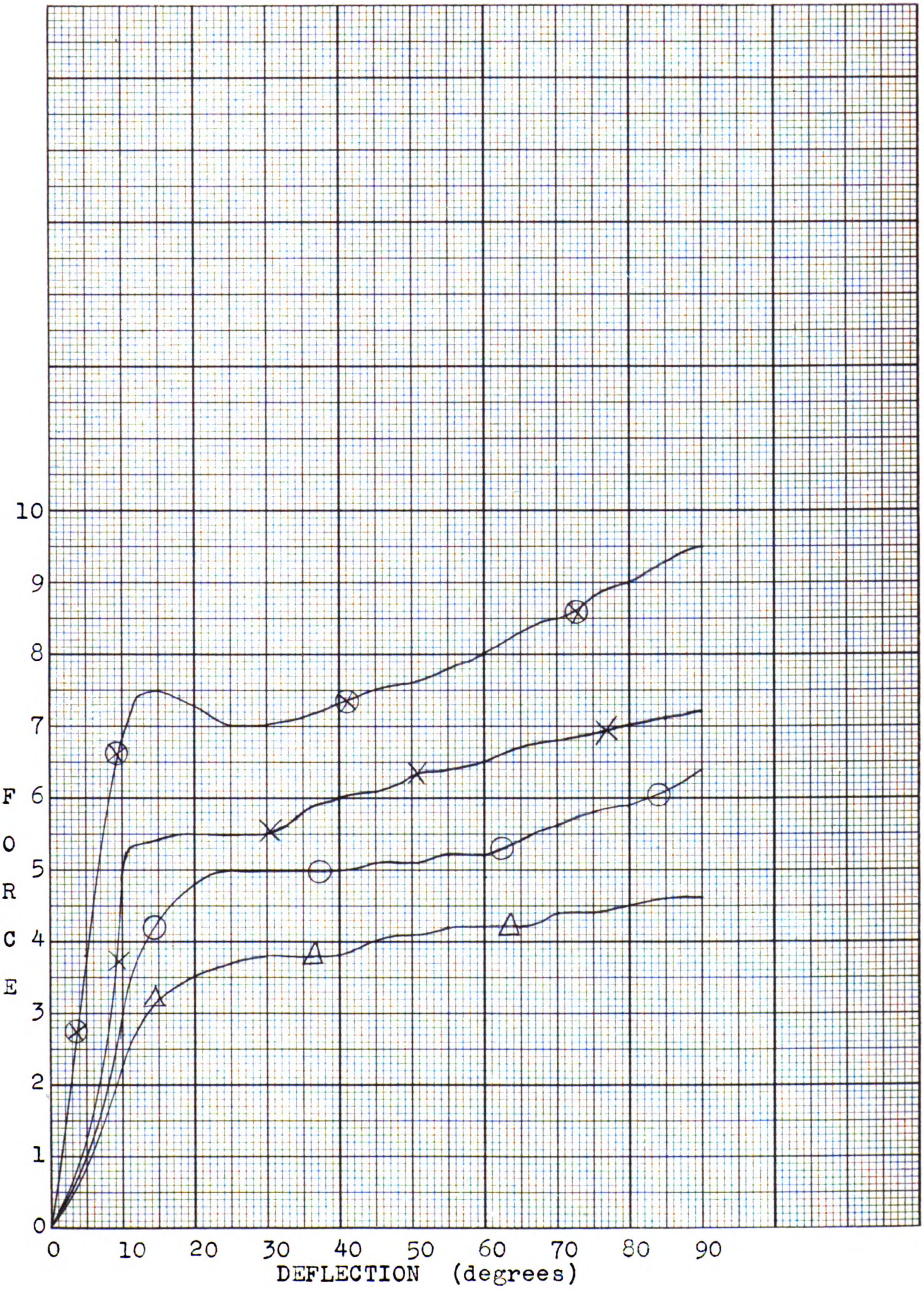
Bending force - angular delfection graph for specimens tested at 150 cycles per minute.

-⊖- MANICO makeready machine direction

-×- MANICO makeready cross direction

-△- Engraved makeready machine direction

-⊗- Engraved makeready cross direction

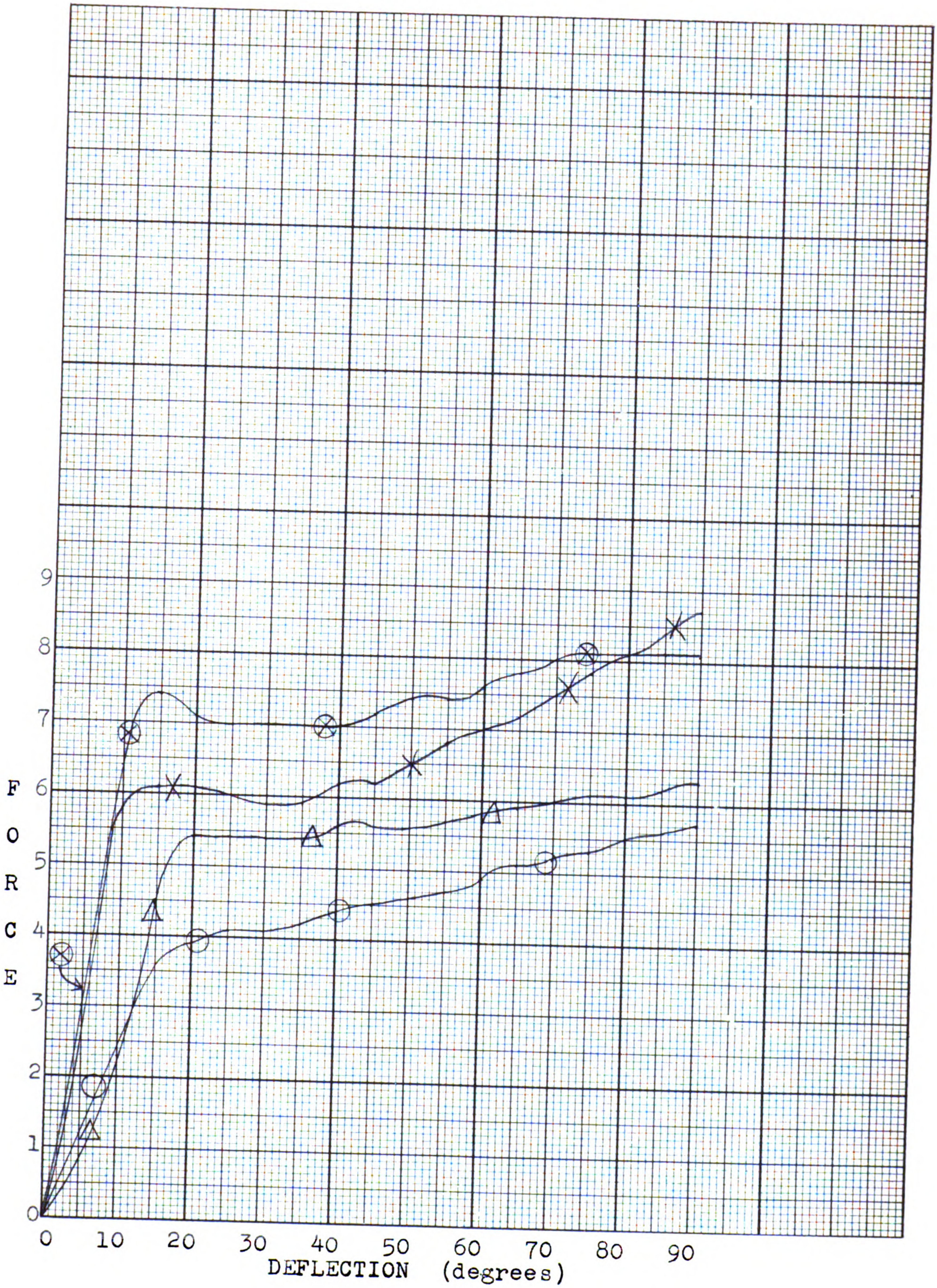


10
9
8
7
6
5
4
3
2
1
0
F
O
R
C
E
0
10
20
30
40
50
60
70
80
90
DEFLECTION (degrees)

GRAPH III

Bending Force - angular deflection graph for specimens tested at 200 cycles per minute.

- MANICO makeready machine direction
- MANCIO makeready cross direction
- Engraved makeready machine direction
- Engraved makeready cross direction



F
O
R
C
E
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
70
80
90
DEFLECTION (degrees)

GRAPH IV

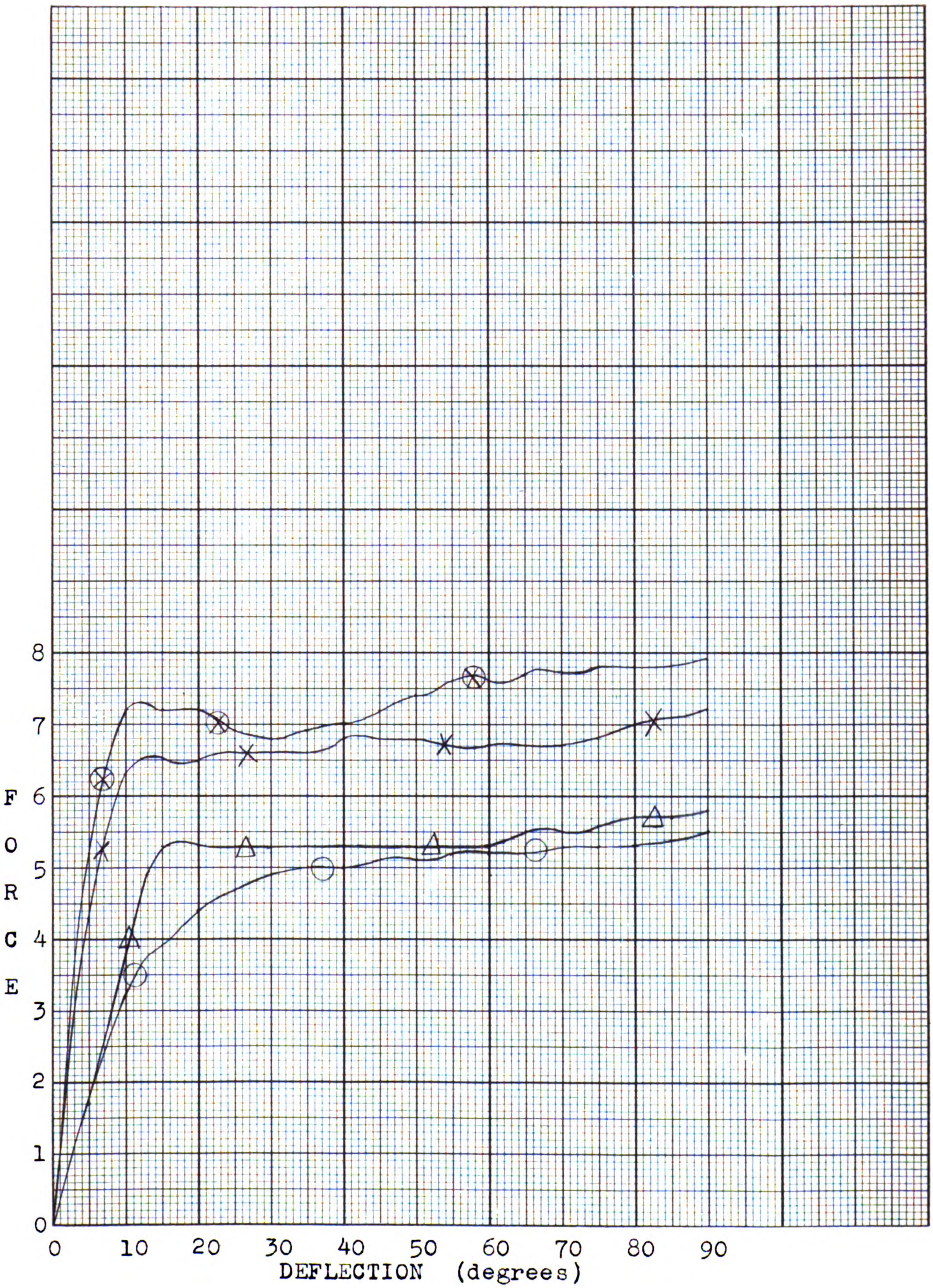
Bending force - angular deflection graph for specimens tested at 250 cycles per minute

MANCIO makeready machine direction

MANICO makeready cross direction

Engraved makeready machine direction

Engraved makeready cross direction



F
O
R
C
E
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
DEFLECTION (degrees)

GRAPH V

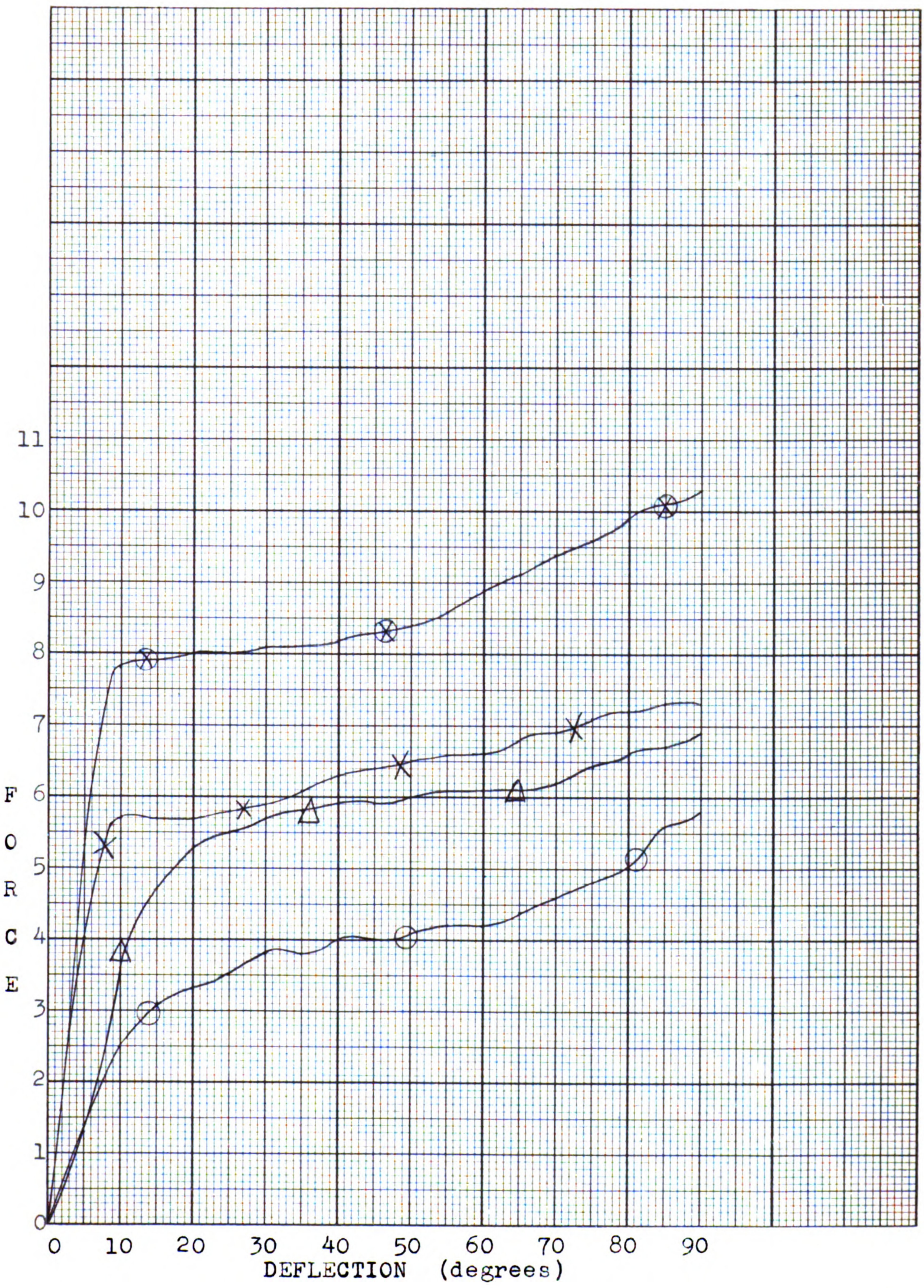
Bending force - angular deflection graph for specimens tested at 300 cycles per minute.

—○— MANICO makeready machine direction

—X— MANICO makeready cross direction

- -△- - Engraved makeready machine direction

—⊗— Engraved makeready cross direction



11
10
9
8
7
6
5
4
3
2
1
0
F
O
R
C
E
0
10
20
30
40
50
60
70
80
90
DEFLECTION (degrees)

GRAPH VI

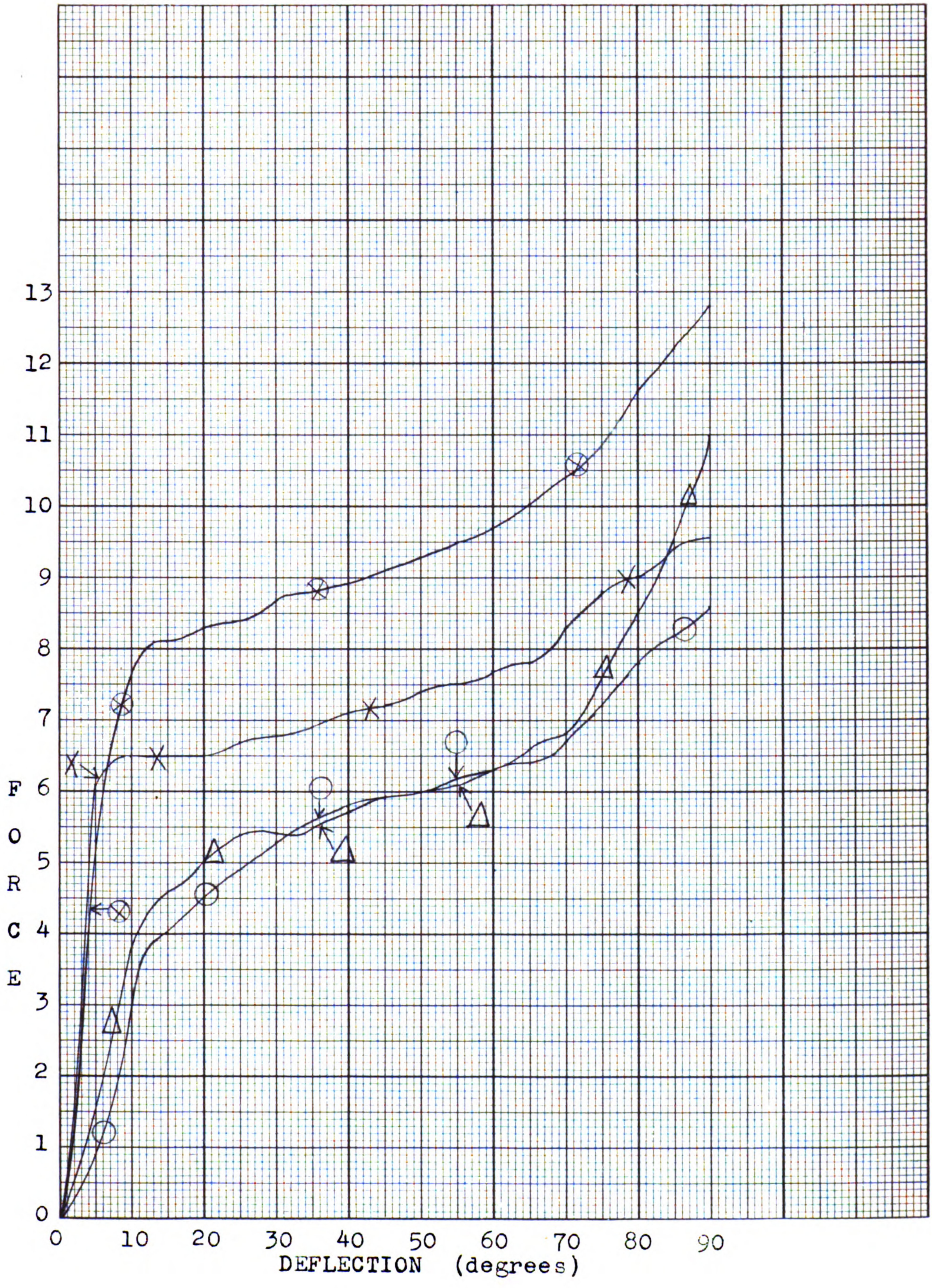
Bending force - angular deflection graph for specimens tested at 350 cycles per minute.

-⊖- MANICO makeready machine direction

-✕- MANICO makeready cross direction

-△- Engraved makeready machine direction

-⊗- Engraved makeready cross direction



F O R C E
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
10
20
30
40
50
60
70
80
90
DEFLECTION (degrees)

GRAPH VII

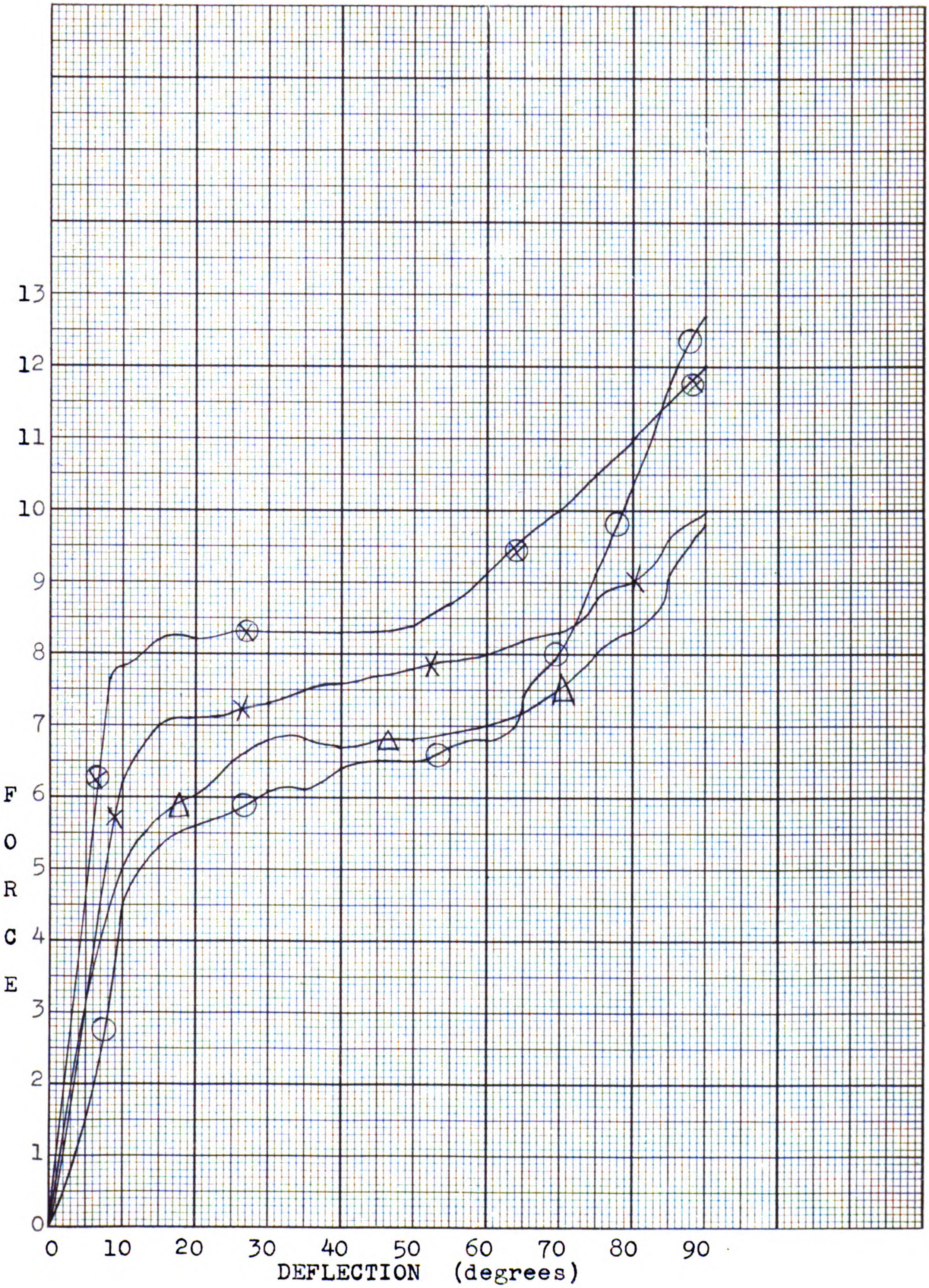
Bending force - angular deflection graph for specimens tested at 400 cycles per minute.

—⊖— MANICO makeready machine direction

✱ MANICO makeready cross direction

—△— Engraved makeready machine direction

—⊗— Engraved makeready cross direction



13
12
11
10
9
8
7
6
5
4
3
2
1
0
F O R C E
0 10 20 30 40 50 60 70 80 90
DEFLECTION (degrees)

APPENDIX D. BENDING FORCE - FREQUENCY GRAPH

GRAPH I

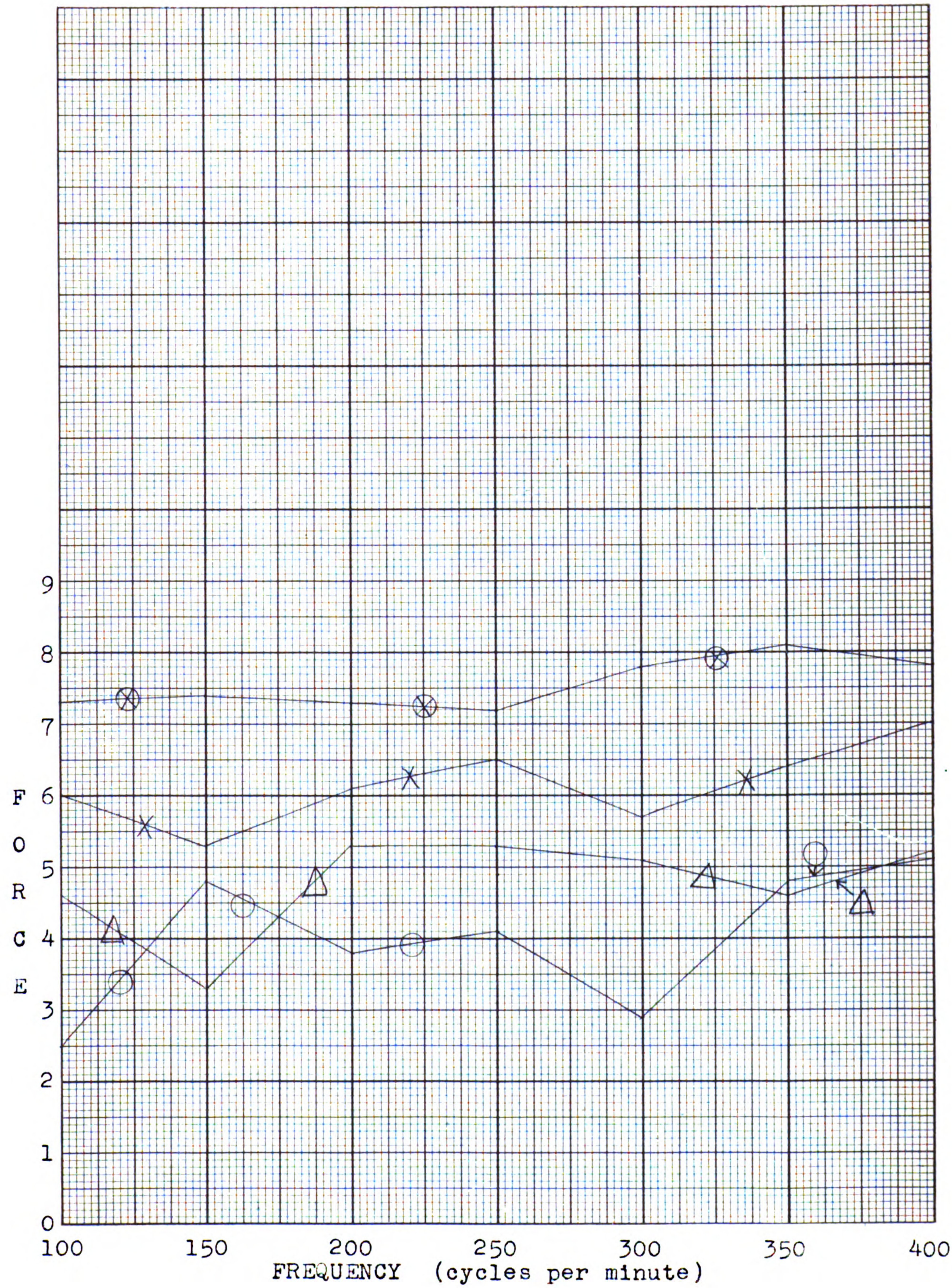
Bending force - frequency graph.

—⊖— MANICO makeready machine direction

—×— MANICO makeready cross direction

—△— Engraved makeready machine direction

—⊗— Engraved makeready cross direction


9
8
7
6
5
4
3
2
1
0
F
O
R
C
E
100
150
200
250
300
350
400
FREQUENCY (cycles per minute)

APPENDIX E. BREAK ANGLE - FREQUENCY GRAPH

GRAPH I

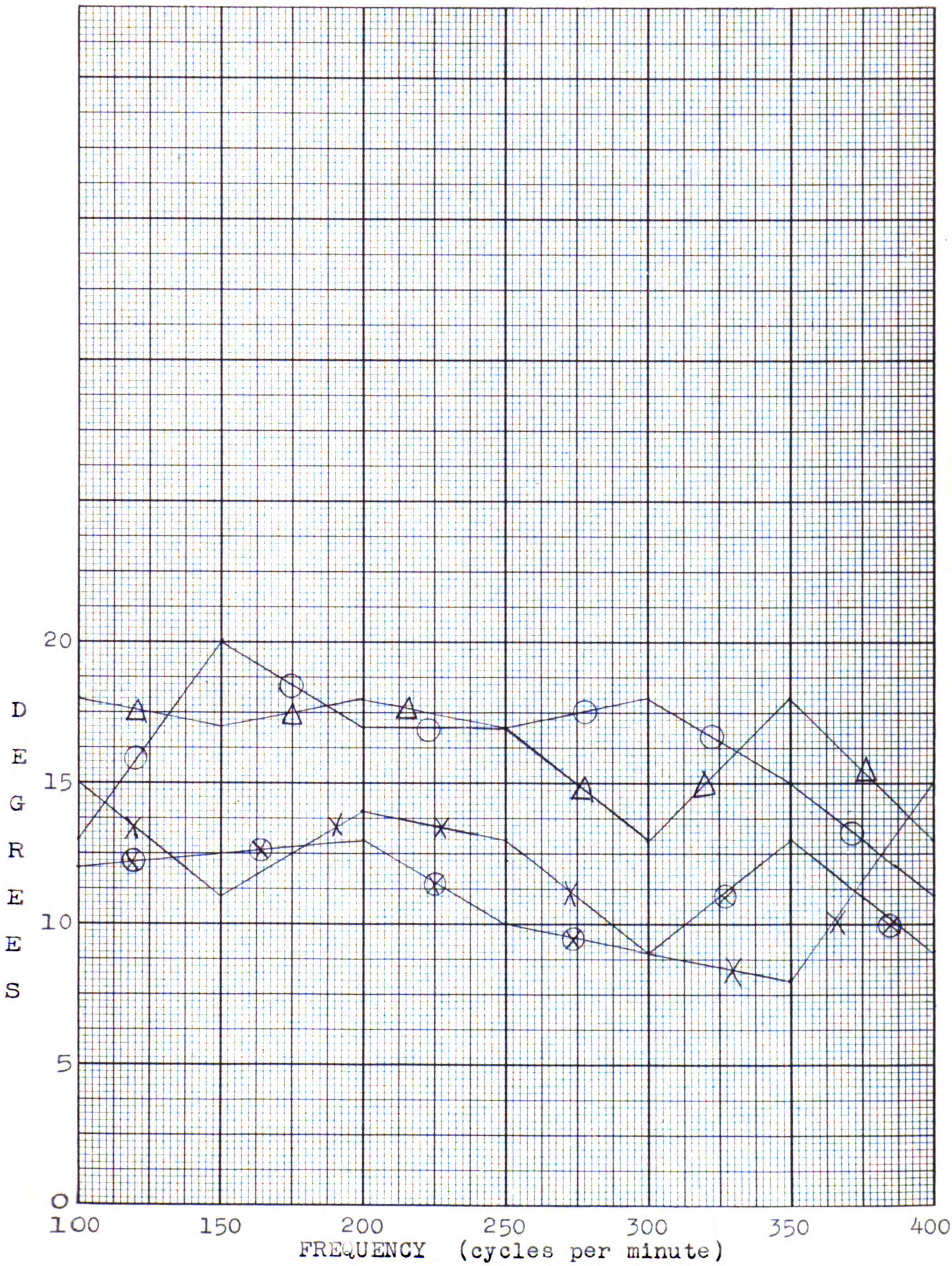
Break angle - frequency graph.

—⊖— MANICO makeready machine direction

—✱— MANICO makeready cross direction

—△— Engraved makeready machine direction

—⊛— Engraved makeready cross direction



DEGREES
0
5
10
15
20
100
150
200
250
300
350
400
FREQUENCY (cycles per minute)

APPENDIX F. SPRINGBACK - FREQUENCY GRAPH

GRAPH I

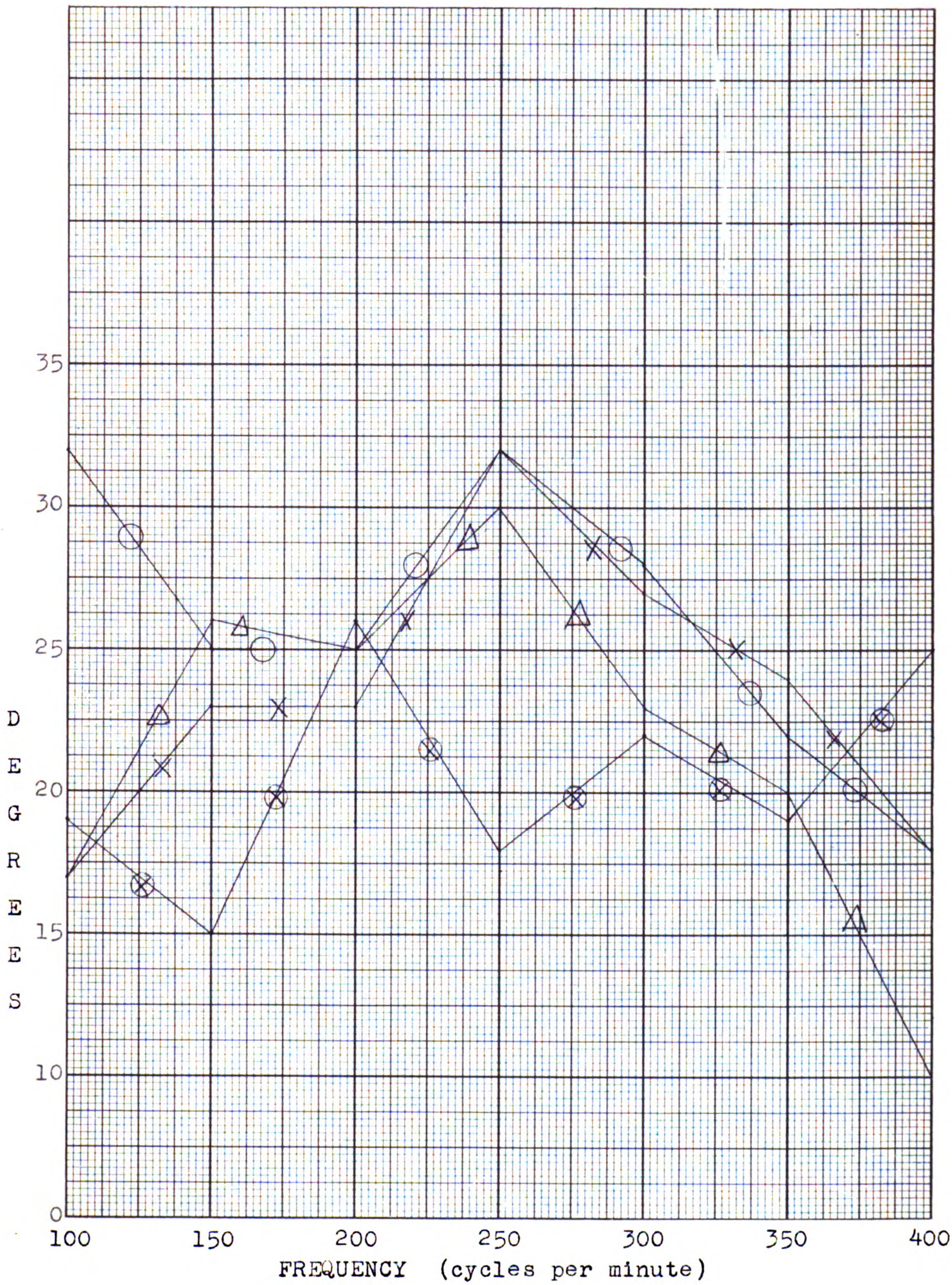
Springback - frequency graph.

MANICO makeready machine direction

MANICO makeready cross direction

Engraved makeready machine direction

Engraved makeready cross direction


35
30
25
20
15
10
0
D
E
G
R
E
E
S
100
150
200
250
300
350
400
FREQUENCY (cycles per minute)