

S H R I N K A G E 85

Influence of Moisture Content on Shrinkage Development  
in Tumble Drying

P A R T 1: Preliminary Trial - Interlock Winch Dye

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C O N T E N T S

1. INTRODUCTION
  
2. PRELIMINARY INVESTIGATION
  - 2.1. Sample Preparation
  - 2.2. Experimental Procedure
  
3. RESULTS
  
4. DISCUSSION
  - 4.1. Length Shrinkage
  - 4.2. Width Shrinkage
  - 4.3. Moisture Content
  
5. CONCLUSIONS

TABLES 1 - 16

FIGURES 1 - 11

## 1. INTRODUCTION

The measurement of shrinkage in knitted cotton fabrics has been the subject of many investigations and research projects both by IIC and others. In particular, IIC's work on cotton knitgoods and the development of the STARFISH model rests on the definition and reliable reproduction of a reference state of relaxation on which to make measurements.

The reference state of relaxation has been defined in terms of a relaxation procedure which consists of one cycle of washing and tumble drying, followed by four cycles of rinsing and tumble drying. Effective utilisation of the STARFISH model by other organisations, however, depends on the ability of other laboratories to reproduce this Reference State.

Previous work has suggested that the conditions of washing (e.g. cycle time, temperature) are not critical to the determination of shrinkage, if tumble drying follows the washing/rinsing cycle, although this is not the case if drying is carried out on, for example, a line. However, although reproducibility is high, when measuring shrinkage to the Reference State in our own laboratory, interlaboratory correlations are less satisfactory. One possible reason for the lack of reproducibility between laboratories may be due to differences in the conditions of tumble drying. In particular the variation in, and the amount of residual moisture remaining in the fabrics under test, at the end of tumble drying.

IIC's test procedure for obtaining the Reference State of relaxation specifies that the standard load should be dried to constant weight after each washing/rinsing cycle. Other laboratories, however, consider that drying to the original conditioned weight of the load (normal regain) should be sufficient. There is, however, evidence to show that cotton knitgoods continue to shrink if tumble drying is continued beyond normal regain until very low levels of residual moisture (less than 1%) are achieved, and that the additional shrinkage which is developed can be significantly higher at near zero moisture than at 6-7% moisture. This is therefore a potential source of variation between laboratories.

To investigate the relationship between moisture content and shrinkage more thoroughly, a preliminary investigation was carried out which was designed to monitor the development of shrinkage and the rate of reduction of moisture content in an interlock winch dyed and finished quality, by making measurements at regular time intervals during a standard 5-cycle relaxation sequence. In the light of the results obtained from this preliminary investigation a further series of trials was devised. In this second series, shrinkage, fabric weight and moisture content were monitored on sets of samples, all prepared from the same piece of interlock winch dyed fabric and washed/wet out according to standard procedures, but which were tumble dried for different lengths of time, including an additional 10 minute cool down period. Measurements were taken at the end of each completed tumble dry cycle and after reconditioning in the laboratory. An additional set of samples, prepared from the same roll and washed under identical conditions, was line dried in a conditioned atmosphere for 24 hours, for comparison. A third series of trials repeated this exercise using tubular mercerised single jersey fabric.

In this report the results of the preliminary investigation are discussed. The results from the second, third, and any subsequent trials will be reported separately.

## 2. PRELIMINARY INVESTIGATION

### 2.1. Sample Preparation

Five standard shrinkage specimens (50 x 50cm<sup>2</sup> template) were prepared from a roll of 20G interlock, knitted from Ne 1/38 combed cotton at 0.338cm nominal stitch length, which had been winch dyed and finished during a separate investigation at Springfield Dyers and Finishers. Each specimen was conditioned in the laboratory, marked, measured and weighed prior to laundering. A standard load of 2.75kg was made up including the test specimens, with make-weight fabric of a similar construction.

Initial moisture content and % regain were determined based on the oven-dried and reconditioned weight of a separate sample taken from the same roll.

### 2.2. Experimental Procedure

The five shrinkage specimens were washed together with the make-weights in a Hoover automatic, domestic washing machine at 60°C.

After completion of the washing cycle the load was transferred to a Hoover domestic, single direction, tumble dryer, and tumble dried on the hottest temperature setting for 30 mins.

At the end of 30 mins the load was removed from the tumble drier, the shrinkage specimens weighed and measured, and then the whole load returned to the tumble dryer.

Measuring and weighing of the shrinkage specimens was repeated at 10 minute intervals until the average weight of the specimens remained constant. This was achieved at 80 minutes, i.e. the average weight of the shrinkage specimens remained constant between 70 and 80 minutes. The drying time for the load was therefore established at 70 minutes and tumble drying after all subsequent cycles was stopped at 70 minutes.

The load was then returned to the washing machine and re-wet out using the rinse cycle. On completion of the rinse cycle the load was transferred to the tumble dryer and dried on the hottest temperature setting for 30 minutes. The load was then removed, the test specimens weighed and measured, and the whole load returned to the tumble dryer. Measurements were taken, as for the first cycle, at 10 minute intervals, until 70 minutes, the drying time for the load established from the first cycle.

The rinse/tumble drying cycles were repeated a further 3 times, with measurements and weights being recorded every 10 minutes from 30 to 70 minutes during tumble drying.

All measurements were made on the specimens taken straight from the tumble dryer without conditioning. During the time that it took to measure and weigh

the shrinkage specimens the tumble dryer was left running at the hottest temperature setting to maintain the temperature in the drum.

### 3. RESULTS

The average shrinkage measurements (3 lengths x 3 widths) for each specimen, for each cycle are given in Tables 1 - 5.

The weights for each specimen are given in Tables 6 - 10. Based on the average % moisture content established on a separate sample of the same fabric, the oven dry weights for each specimen were calculated from the original conditioned weights.

Using the calculated oven dry weight for each specimen, the % moisture content of each specimen at the different time intervals over the 5 cycles were calculated using the formula:-

$$\% \text{ moisture content} = \left[ \frac{\text{Specimen weight} - \text{calc. oven dry weight}}{\text{Specimen weight}} \right] \times 100$$

These results are given in Tables 11 - 15.

In Table 16 the average results for the 5 replications for % moisture content, % length and width shrinkages including standard deviations are given for each of the five cycles.

Plots of the average, individual results and standard deviations are given in Figures 1 - 3 for length shrinkage, 4 - 6 for width shrinkage, and 7 - 10 for moisture content, Figures 11 (for length) and 12 (for width) combine the average results for shrinkage and moisture content for all cycles. The dotted line represents the original conditioned average moisture content of the shrinkage specimens.

### 4. DISCUSSION

#### 4.1. Length Shrinkage

Tables 1 - 5, Figures 1-3, 10.

Length shrinkage recorded on the test specimens increased progressively both with time in the tumble dryer (reducing moisture content) and over the number of cycles. Variation in the measurements as described by the standard deviations (Figure 3) do not however point to a significant reduction in variability as moisture content decreased, after the first cycle. On average the standard deviations were found to be in the region of 0.5% at the end of the drying time.

From Figure 10 however it is clear that maximum length shrinkage was only developed after the average moisture content of the specimens fell below their original moisture content, and levelled out as the residual moisture content approached zero.

#### 4.2. Width Shrinkage

Tables 1 -5, Figures 4-6, 11.

Width shrinkage increased with time in the tumble dryer (reducing moisture content) but was not progressive over cycles. Variation in the measurements however generally improved as moisture content decreased (Figure 6) although they were generally higher than those recorded for length shrinkage. Final standard deviations were on average 1% at the end of the drying time.

Similarly to length shrinkage, Figure 11 shows that maximum width shrinkage was only developed after the average moisture content in the test specimens fell below original moisture content, and levelled out as the residual moisture content approached zero.

#### 4.3. Moisture Content

Tables 11 - 15, Figures 7-11.

Moisture content decreased with time in the tumble dryer and apparently with number of cycles. Moisture contents recorded after 30 minutes generally decreased with each consecutive cycle. This may be due to a decreased pick up in cold rinse cycles with no detergent as opposed to a hot, full wash with detergent in the 1st cycle. It may also be due to gradual weight loss in the specimens over cycles.

Variation in moisture content between the test specimens however was high during the earlier stages of drying but decreased to very low levels, less than 0.2% standard deviation by the end of the drying cycle. This is to be expected since, at higher moisture contents, evaporation will continue during handling and weighing.

#### 5. CONCLUSIONS

1. Both length and width shrinkage increases as moisture content in the fabric is reduced, but does not reach maximum until the residual moisture content falls below normal regain and approaches zero.
2. For this interlock quality, length shrinkage is progressive over cycles, but maximum width shrinkage is achieved by the end of the first cycle.
3. Shrinkage results for length are less variable than for width and after the first cycle are not improved significantly as moisture content falls.
4. Shrinkage results for width are more variable than for length and improve as the residual moisture content in the fabrics approaches zero.

5. Variation in the moisture content between test specimens is high during the early stages of drying but is very low at the end of the drying cycle, i.e. when the fabrics are uniformly dry.
6. These results support the idea that, to develop the maximum shrinkage and to obtain the best reproducibility of results, tumble drying should continue until the specimens achieve constant weight.

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# SHRINKAGE IN TUMBLE DRYING

TABLE 1

SET 0 : 206 INTERLOCK. Ne 1/38. SL 0.338cm. FINISH WINCH DYE

1st CYCLE : FULL WASH + TUMBLE DRY

SHRINKAGE MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	30 Mins :		40 Mins :		50 Mins :		60 Mins :		70 Mins :		80 Mins	
	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ
A	11.96	3	13.1	3.26	16.51	9.44	17.52	10.8	18	10.54	17.9	10.34
B	10.98	3.57	13.12	4.37	12.92	3.51	17.72	11.4	18.05	11.12	17.66	11.65
C	14.77	2.27	15.37	2.33	14.02	6.84	18.6	11.53	19.2	11.47	19.61	11.2
D	11.31	2.32	14.26	3.32	14.66	6.89	17.67	8.87	18.53	9.77	18.41	9.61
E	12.36	1.25	12.63	2.9	14.29	1.85	17.03	8.76	18.18	9	17.98	8.74

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	30	LSZ	5	12.2760	1.4950	12.18
2.	Mins	WSZ	5	2.4820	0.8719	35.13
3.	40	LSZ	5	13.6960	1.1117	8.12
4.	Mins	WSZ	5	3.2360	0.7462	23.06
5.	50	LSZ	5	14.4800	1.3072	9.03
6.	Mins	WSZ	5	5.7060	3.0134	52.81
7.	60	LSZ	5	17.7080	0.5684	3.21
8.	Mins	WSZ	5	10.2720	1.3588	13.23
9.	70	LSZ	5	18.3920	0.4969	2.70
10.	Mins	WSZ	5	10.3080	1.0047	9.68
11.	80	LSZ	5	18.3120	0.7745	4.23
12.	Mins	WSZ	5	10.3080	1.1772	11.42



SHRINKAGE IN TUMBLE DRYING

SET 0 : 20G INTERLOCK, Ne 1/30, SL 0.338cm, FINISH WINCH DYE

2nd CYCLE : 1st RINSE + TUMBLE DRY

SHRINKAGE MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	30 Mins :		40 Mins :		50 Mins :		60 Mins :		70 Mins :		80 Mins	
	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ
A	14.58	4.86	16.53	-2	20.5	8	20.3	9.6	20.44	9.14	n.a.	n.a.
B	14.62	3.51	16.32	9.33	19.31	11	20.05	11.4	20.25	11.51	n.a.	n.a.
C	14.71	3.57	17.53	4.92	18.05	10.24	21.22	11.78	21.42	11.58	n.a.	n.a.
D	15	3.28	16.81	3.57	19.34	10.4	20.34	10.13	20.08	10.26	n.a.	n.a.
E	15.09	4.29	15.17	5.03	19.3	6.68	20.3	9	20.3	9.4	n.a.	n.a.

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	30	LSZ	5	14.8000	0.2308	1.56
2.	Mins	WSZ	5	3.9020	0.6556	16.80
3.	40	LSZ	5	16.4720	0.8595	5.22
4.	Mins	WSZ	5	4.1700	4.0730	97.67
5.	50	LSZ	5	19.3000	0.8666	4.49
6.	Mins	WSZ	5	9.2640	1.8393	19.85
7.	60	LSZ	5	20.4420	0.4499	2.20
8.	Mins	WSZ	5	10.3820	1.1806	11.37
9.	70	LSZ	5	20.4980	0.5312	2.59
10.	Mins	WSZ	5	10.3780	1.1434	11.02
11.	80	LSZ	0	0.0000	0.0000	0.00
12.	Mins	WSZ	0	0.0000	0.0000	0.00

SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK, Ne 1/38, SL 0.338cm, FINISH WINCH DYE

3rd CYCLE : 2nd RINSE + TUMBLE DRY

SHRINKAGE MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	30 Mins :		40 Mins :		50 Mins :		60 Mins :		70 Mins :		80 Mins :	
	LSZ	WSZ	LSZ	WSZ	LSZ	WSZ	LSZ	WSZ	LSZ	WSZ	LSZ	WSZ
A	18.19	0.36	16.87	4.94	19.98	10.06	21.09	9.8	21.49	9.14	n.a.	n.a.
B	16.32	3.71	17.91	3.57	19.91	10.8	20.71	11.12	20.87	10.66	n.a.	n.a.
C	18.54	2.33	17.91	6.65	21.00	11.33	22.28	12.1	22.22	11.60	n.a.	n.a.
D	16.93	-0.26	17.21	4.86	19.54	10.2	21.02	9.81	20.58	10.13	n.a.	n.a.
E	17.98	0.99	18.34	4.83	20.18	9.66	21.18	9.54	21.44	9.4	n.a.	n.a.

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	30	LSZ	5	17.5920	0.9305	5.29
2.	Mins	WSZ	5	1.4260	1.5971	112.00
3.	40	LSZ	5	17.6480	0.5944	3.37
4.	Mins	WSZ	5	4.9700	1.0972	22.08
5.	50	LSZ	5	20.1380	0.5753	2.86
6.	Mins	WSZ	5	10.4100	0.6572	6.31
7.	60	LSZ	5	21.2560	0.5991	2.82
8.	Mins	WSZ	5	10.4740	1.0987	10.49
9.	70	LSZ	5	21.3200	0.6331	2.97
10.	Mins	WSZ	5	10.2020	1.0211	10.01
11.	80	LSZ	0	0.0000	0.0000	0.00
12.	Mins	WSZ	0	0.0000	0.0000	0.00

SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK, Ne 1/38, SL 0.338cm, FINISH WINCH DYE

4th CYCLE : 3rd RINSE + TUMBLE DRY

SHRINKAGE MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	30 Mins :		40 Mins :		50 Mins :		60 Mins :		70 Mins :		80 Mins	
	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ
A	18.59	-1.64	18.71	7.74	21.29	9.26	21.88	10	21.88	9.4	n.a.	n.a.
B	18.25	-0.99	18.31	8.68	20.71	11.32	21.51	11.42	21.11	12.09	n.a.	n.a.
C	19.46	0.87	19.61	2.14	22.02	9.46	22.02	10.7	22.49	10.81	n.a.	n.a.
D	17.61	-1.85	17.93	2.38	20.08	5.9	22.35	9.53	21.95	9.61	n.a.	n.a.
E	17.98	2.5	18.88	2.15	21.18	9.34	22.18	9.14	21.7	9.4	n.a.	n.a.

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	30	LSZ	5	18.3700	0.7036	3.83
2.	Mins	WSZ	5	-0.2220	1.8610	838.27
3.	40	LSZ	5	18.6880	0.6334	3.39
4.	Mins	WSZ	5	4.6180	3.2972	71.40
5.	50	LSZ	5	21.0560	0.7197	3.42
6.	Mins	WSZ	5	9.0560	1.9603	21.65
7.	60	LSZ	5	21.9880	0.3198	1.45
8.	Mins	WSZ	5	10.1580	0.9141	9.00
9.	70	LSZ	5	21.8260	0.4969	2.28
10.	Mins	WSZ	5	10.2620	1.1782	11.48
11.	80	LSZ	0	0.0000	0.0000	0.00
12.	Mins	WSZ	0	0.0000	0.0000	0.00

## SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK, Ne 1/30, SL 0.330cm, FINISH WINCH DYE

5th CYCLE : 4th RINSE + TUMBLE DRY

SHRINKAGE MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	30 Mins :		40 Mins :		50 Mins :		60 Mins :		70 Mins :		80 Mins	
	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ :	LSZ	WSZ
A	19.9	-2.36	17.3	5.74	21.69	9.2	22.76	9.86	22.62	9.2	n.a.	n.a.
B	19.25	1.39	18.71	2.88	21.05	10.6	21.81	11.26	21.71	10.6	n.a.	n.a.
C	19.34	5.32	20.61	5.74	22.22	11.66	23.27	11.72	22.89	11.2	n.a.	n.a.
D	19.08	-2.98	19.08	-2.64	19.08	7.68	22.03	10.2	22.03	8.52	n.a.	n.a.
E	18.78	-1.47	19.58	1.51	19.9	9.44	22.51	9.85	22.71	9.66	n.a.	n.a.

## \*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	30	LSZ	5	19.2700	0.4118	2.14
2.	Mins	WSZ	5	-0.0200	3.4221	17110.56
3.	40	LSZ	5	19.0560	1.2138	6.37
4.	Mins	WSZ	5	2.6460	3.4797	131.51
5.	50	LSZ	5	20.9480	1.0509	5.02
6.	Mins	WSZ	5	9.7160	1.5040	15.48
7.	60	LSZ	5	22.4760	0.5820	2.59
8.	Mins	WSZ	5	10.5780	0.8599	8.13
9.	70	LSZ	5	22.3920	0.4993	2.23
10.	Mins	WSZ	5	9.8360	1.0737	10.92
11.	80	LSZ	0	0.0000	0.0000	0.00
12.	Mins	WSZ	0	0.0000	0.0000	0.00

SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK. Ne 1/38. SL 0.330cm. FINISH WINCH DYE

1st CYCLE : FULL WASH + TUMBLE DRY

SAMPLE WEIGHTS gms MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	90.136	96.506	121.078	104.771	94.314	92.254	90.925	90.873
B	86.521	92.635	140.951	121.12	105.405	88.14	87.13	87.22
C	85.697	91.752	128.483	111.751	98.384	87.759	86.251	86.284
D	78.969	84.549	117.294	105.338	86.759	81.809	79.73	79.79
E	82.595	88.431	131.189	118.974	102.116	85.552	83.277	83.285

NB Oven Dry sample weights calculated from Original Conditioned sample weights using Average Moisture Content established on samples of the same fabric in a separate test.

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven	Dry	5	84.7836	4.2162	4.97
2.	Orig	Cond	5	90.7747	4.5142	4.97
3.	30	Mins	5	127.7993	9.2259	7.22
4.	40	Mins	5	112.3909	7.5459	6.71
5.	50	Mins	5	97.3958	7.2464	7.44
6.	60	Mins	5	86.9427	4.1065	4.72
7.	70	Mins	5	85.4627	4.2095	4.93
8.	80	Mins	5	85.4743	4.1926	4.91

SHRINKAGE IN TUMBLE DRYING

TABLE 7

SET 0 : 206 INTERLOCK. Ne 1/38. SL 0.338cm. FINISH WINCH DYE

2nd CYCLE : 1st RINSE + TUMBLE DRY

SAMPLE WEIGHTS gms MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	90.136	96.506	126.678	108.486	93.136	90.848	90.802	n.a.
B	86.521	92.635	111.296	96.285	89.415	87.108	87.01	n.a.
C	85.697	91.752	129.063	113.253	92.695	86.499	86.283	n.a.
D	78.969	84.549	112.552	98.786	81.91	79.859	79.806	n.a.
E	82.595	88.431	117.248	99.268	86.495	83.474	83.056	n.a.

NB Oven Dry sample weights calculated from Original Conditioned sample weights using Average Moisture Content established on samples of the same fabric in a separate test.

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven Dry		5	84.7836	4.2162	4.97
2.	Orig Cond		5	90.7747	4.5142	4.97
3.	30 Mins		5	119.3677	8.1169	6.80
4.	40 Mins		5	103.2158	7.2761	7.05
5.	50 Mins		5	88.7301	4.6667	5.26
6.	60 Mins		5	85.5576	4.1258	4.82
7.	70 Mins		5	85.3917	4.1635	4.88
8.	80 Mins		0	0.0000	0.0000	0.00

SHRINKAGE IN TUMBLE DRYING

TABLE 8

SET 0 : 206 INTERLOCK. Ne 1/30. SL 0.338cm. FINISH WINCH DYE

3rd CYCLE : 2nd RINSE + TUMBLE DRY

SAMPLE WEIGHTS gms MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	90.136	96.506	119.156	103.908	93.158	90.837	90.661	n.a.
B	86.521	92.635	120.538	103.887	90.417	87.012	87.392	n.a.
C	85.697	91.752	113.038	99.309	89.21	86.459	86.456	n.a.
D	78.969	84.549	116.085	96.623	82.433	79.496	79.67	n.a.
E	82.595	88.431	107.406	94.732	86.09	83.52	83.165	n.a.

NB Oven Dry sample weights calculated from Original Conditioned sample weights using Average Moisture Content established on samples of the same fabric in a separate test.

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven	Dry	5	84.7836	4.2162	4.97
2.	Orig	Cond	5	90.7747	4.5142	4.97
3.	30	Mins	5	115.2449	5.2520	4.56
4.	40	Mins	5	99.6921	4.1695	4.18
5.	50	Mins	5	88.2617	4.1294	4.68
6.	60	Mins	5	85.4652	4.2324	4.95
7.	70	Mins	5	85.4688	4.2002	4.91
8.	80	Mins	0	0.0000	0.0000	0.00

SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK. Ne 1/38. SL 0.338cm. FINISH WINCH DYE

4th CYCLE : 3rd RINSE + TUMBLE DRY

SAMPLE WEIGHTS gms MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	90.136	96.506	117.365	99.508	92.233	90.346	90.613	n.a.
B	86.521	92.635	115.345	97.544	88.589	86.822	86.939	n.a.
C	85.697	91.752	120.557	103.491	88.339	85.901	86.107	n.a.
D	78.969	84.549	118.911	102.775	85.63	79.905	79.436	n.a.
E	82.595	88.431	113.34	96.737	86.038	82.82	82.875	n.a.

NB Oven Dry sample weights calculated from Original Conditioned sample weights using Average Moisture Content established on samples of the same fabric in a separate test.

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven	Drv	5	84.7836	4.2162	4.97
2.	Orig	Cond	5	90.7747	4.5142	4.97
3.	30	Mins	5	117.1038	2.8513	2.43
4.	40	Mins	5	100.0111	3.0333	3.03
5.	50	Mins	5	88.1659	2.6319	2.99
6.	60	Mins	5	85.1590	3.9777	4.67
7.	70	Mins	5	85.1941	4.2361	4.97
8.	80	Mins	0	0.0000	0.0000	0.00



SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK. Ne 1/38. SL 0.338cm. FINISH WINCH DYE

5th CYCLE : 4th RINSE + TUMBLE DRY

SAMPLE WEIGHTS ~~gas~~ MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	90.136	96.506	114.905	103.141	93.739	90.5	90.684	n.a.
B	86.521	92.635	112.783	113.107	89.489	86.835	87.2	n.a.
C	85.697	91.752	108.811	95.454	88.416	85.906	86.288	n.a.
D	78.969	84.549	121.802	106.282	85.408	79.634	79.679	n.a.
E	82.595	88.431	115.617	99.206	85.45	82.732	82.967	n.a.

NB Oven Dry sample weights calculated from Original Conditioned sample weights using Average Moisture Content established on samples of the same fabric in a separate test.

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven	Drv	5	84.7836	4.2162	4.97
2.	Orig	Cond	5	90.7747	4.5142	4.97
3.	30	Mins	5	114.7838	4.7339	4.12
4.	40	Mins	5	103.4380	6.7698	6.54
5.	50	Mins	5	88.5004	3.4387	3.89
6.	60	Mins	5	85.1217	4.1321	4.85
7.	70	Mins	5	85.3637	4.2010	4.92
8.	80	Mins	0	0.0000	0.0000	0.00

SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK, Ne 1/38, SL 0.338cm, FINISH WINCH DYE

1st CYCLE : FULL WASH + TUMBLE DRY

% MOISTURE CONTENT MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	0	6.6	25.56	13.97	4.43	2.3	0.87	0.81
B	0	6.6	38.62	28.57	17.92	1.84	0.7	0.8
C	0	6.6	33.3	23.31	12.9	2.35	0.64	0.68
D	0	6.6	32.67	25.03	8.89	2.52	0.96	1.03
E	0	6.6	37.04	30.58	19.12	3.46	0.82	0.73

1) % Moisture Content calculated from sample weights

$$\%MC = (\text{Sample Weight} - \text{Oven Dry Weight}) / \text{Sample Weight} * 100$$

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven Dry		5	0.0000	0.0000	0.00
2.	Orig Cond		5	6.6000	0.0000	0.00
3.	30 Mins		5	33.4380	5.0621	15.14
4.	40 Mins		5	24.2920	6.4400	26.51
5.	50 Mins		5	12.6520	6.1523	48.63
6.	60 Mins		5	2.4940	0.5958	23.89
7.	70 Mins		5	0.7980	0.1289	16.16
8.	80 Mins		5	0.8100	0.1340	16.54

SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK, Ne 1/38, SL 0.338cm, FINISH WINCH DYE

2nd CYCLE : 1st RINSE + TUMBLE DRY

% MOISTURE CONTENT MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	0	6.6	28.85	16.91	3.22	0.78	0.73	n.a.
B	0	6.6	22.26	18.14	3.24	0.67	0.56	n.a.
C	0	6.6	33.6	24.33	7.55	0.93	0.68	n.a.
D	0	6.6	29.84	20.86	3.59	1.11	1.05	n.a.
E	0	6.6	29.56	16.8	4.51	1.05	0.56	n.a.

1) % Moisture Content calculated from sample weights

$$\%MC = (\text{Sample Weight} - \text{Oven Dry Weight}) / \text{Sample Weight} * 100$$

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven Dry		5	0.0000	0.0000	0.00
2.	Orig Cond		5	6.6000	0.0000	0.00
3.	30 Mins		5	28.8220	4.1070	14.25
4.	40 Mins		5	17.6480	5.1986	29.46
5.	50 Mins		5	4.4220	1.8253	41.28
6.	60 Mins		5	0.9080	0.1834	20.19
7.	70 Mins		5	0.7160	0.2011	28.08
8.	80 Mins		0	0.0000	0.0000	0.00

## SHRINKAGE IN TUMBLE DRYING

SET 0 : 20G INTERLOCK, Ne 1/38, SL 0.338cm, FINISH WINCH DYE

3rd CYCLE : 2nd RINSE + TUMBLE DRY

% MOISTURE CONTENT MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	0	6.6	24.35	13.25	3.24	0.77	0.58	n.a.
B	0	6.6	28.22	16.72	4.31	0.56	1	n.a.
C	0	6.6	24.19	13.71	3.94	0.88	0.88	n.a.
D	0	6.6	31.97	18.27	4.2	0.66	0.88	n.a.
E	0	6.6	23.1	12.81	4.06	1.11	0.69	n.a.

1) % Moisture Content calculated from sample weights

$$\%MC = (\text{Sample Weight} - \text{Oven Dry Weight}) / \text{Sample Weight} * 100$$

## \*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven	Dry	5	0.0000	0.0000	0.00
2.	Orig	Cond	5	6.6000	0.0000	0.00
3.	30	Mins	5	26.3660	3.6847	13.98
4.	40	Mins	5	14.9520	2.4064	16.09
5.	50	Mins	5	3.9500	0.4208	10.65
6.	60	Mins	5	0.7960	0.2124	26.69
7.	70	Mins	5	0.8060	0.1682	20.86
8.	80	Mins	0	0.0000	0.0000	0.00

SHRINKAGE IN TUMBLE DRYING

TABLE 14

SET 0 : 206 INTERLOCK, Ne 1/38, SL 0.338cm, FINISH WINCH DYE

4th CYCLE : 3rd RINSE + TUMBLE DRY

% MOISTURE CONTENT MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	0	6.6	23.2	9.42	2.27	0.23	0.53	n.a.
B	0	6.6	24.99	11.3	2.33	0.35	0.48	n.a.
C	0	6.6	28.92	17.19	2.99	0.24	0.48	n.a.
D	0	6.6	33.59	23.16	7.78	1.17	0.59	n.a.
E	0	6.6	27.13	14.62	4	0.27	0.34	n.a.

1) % Moisture Content calculated from sample weights  
 $ZMC = (\text{Sample Weight} - \text{Oven Dry Weight}) / \text{Sample Weight} * 100$

\*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven	Dry	5	0.0000	0.0000	0.00
2.	Orig	Cond	5	6.6000	0.0000	0.00
3.	30	Mins	5	27.5660	4.0003	14.51
4.	40	Mins	5	15.1380	5.3911	35.61
5.	50	Mins	5	3.8740	2.2919	59.16
6.	60	Mins	5	0.4520	0.4041	89.41
7.	70	Mins	5	0.4840	0.0924	19.08
8.	80	Mins	0	0.0000	0.0000	0.00

## SHRINKAGE IN TUMBLE DRYING

SET 0 : 206 INTERLOCK, No 1/38, SL 0.338cm, FINISH WINCH DYE

5th CYCLE : 4th RINSE + TUMBLE DRY

% MOISTURE CONTENT MEASURED STRAIGHT FROM THE TUMBLE DRYER

Sample Reference	Oven Dry	Orig Cond	30 Mins	40 Mins	50 Mins	60 Mins	70 Mins	80 Mins
A	0	6.6	21.56	12.61	3.84	0.4	0.6	n.a.
B	0	6.6	23.29	23.51	3.32	0.36	0.78	n.a.
C	0	6.6	21.24	10.22	3.08	0.24	0.69	n.a.
D	0	6.6	35.17	25.7	7.54	0.84	0.89	n.a.
E	0	6.6	28.56	16.74	3.34	0.17	0.45	n.a.

1) % Moisture Content calculated from sample weights

$$\%MC = (\text{Sample Weight} - \text{Oven Dry Weight}) / \text{Sample Weight} * 100$$

## \*\*\* COLUMN STATISTICS \*\*\*

			N	Mean	SD	CV%
1.	Oven	Drv	5	0.0000	0.0000	0.00
2.	Orig	Cond	5	6.6000	0.0000	0.00
3.	30	Mins	5	25.9640	5.9235	22.81
4.	40	Mins	5	17.7560	6.7179	37.83
5.	50	Mins	5	4.2240	1.8742	44.37
6.	60	Mins	5	0.4020	0.2616	65.07
7.	70	Mins	5	0.6820	0.1684	24.70
8.	80	Mins	0	0.0000	0.0000	0.00

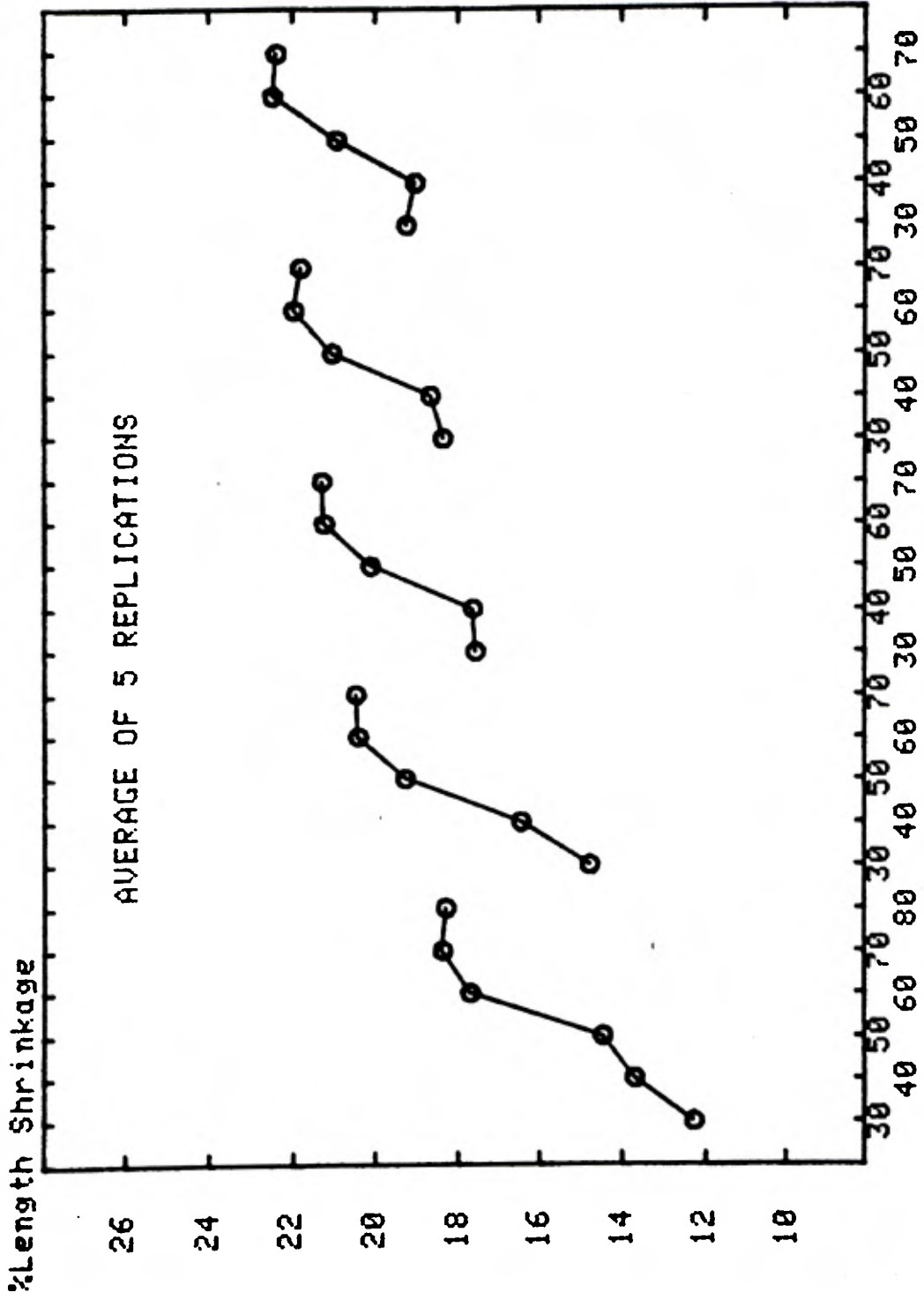
## SHRINKAGE IN TUMBLE DRYING

SET 0 : 20G INTERLOCK, Ne 1/38, SL 0.338cm, FINISH WINCH DYE

Average of 5 replications

	Time	%MC	SD	%LS	SD	%WS	SD
1st Cycle	30	33.44	5.06	12.28	1.5	2.48	0.87
	40	24.29	6.44	13.7	1.11	3.24	0.75
	50	12.65	6.15	14.48	1.31	5.71	3.01
	60	2.49	0.6	17.71	0.57	10.27	1.36
	70	0.8	0.13	18.39	0.5	10.38	1
	80	0.81	0.13	18.31	0.77	10.31	1.18
2nd Cycle	30	28.82	4.11	14.8	0.23	3.9	0.66
	40	17.65	5.2	16.47	0.86	4.17	4.07
	50	4.42	1.83	19.3	0.87	9.26	1.84
	60	0.91	0.18	20.44	0.45	10.38	1.18
	70	0.72	0.2	20.5	0.53	10.38	1.14
3rd Cycle	30	26.37	3.68	17.59	0.93	1.43	1.6
	40	14.95	2.41	17.65	0.59	4.97	1.1
	50	3.95	0.42	20.14	0.58	10.41	0.66
	60	0.8	0.21	21.26	0.6	10.47	1.1
	70	0.81	0.17	21.32	0.63	10.2	1.02
4th Cycle	30	27.57	4	18.38	0.7	-0.22	1.86
	40	15.14	5.39	18.69	0.63	4.62	3.3
	50	3.87	2.29	21.06	0.72	9.06	1.96
	60	0.45	0.4	21.99	0.32	10.16	0.91
	70	0.48	0.09	21.83	0.5	10.26	1.18
5th Cycle	30	25.96	5.92	19.27	0.41	-0.02	3.42
	40	17.76	6.72	19.06	1.21	2.65	3.48
	50	4.22	1.87	20.95	1.05	9.72	1.5
	60	0.4	0.26	22.48	0.58	10.58	0.86
	70	0.68	0.17	22.39	0.5	9.84	1.07

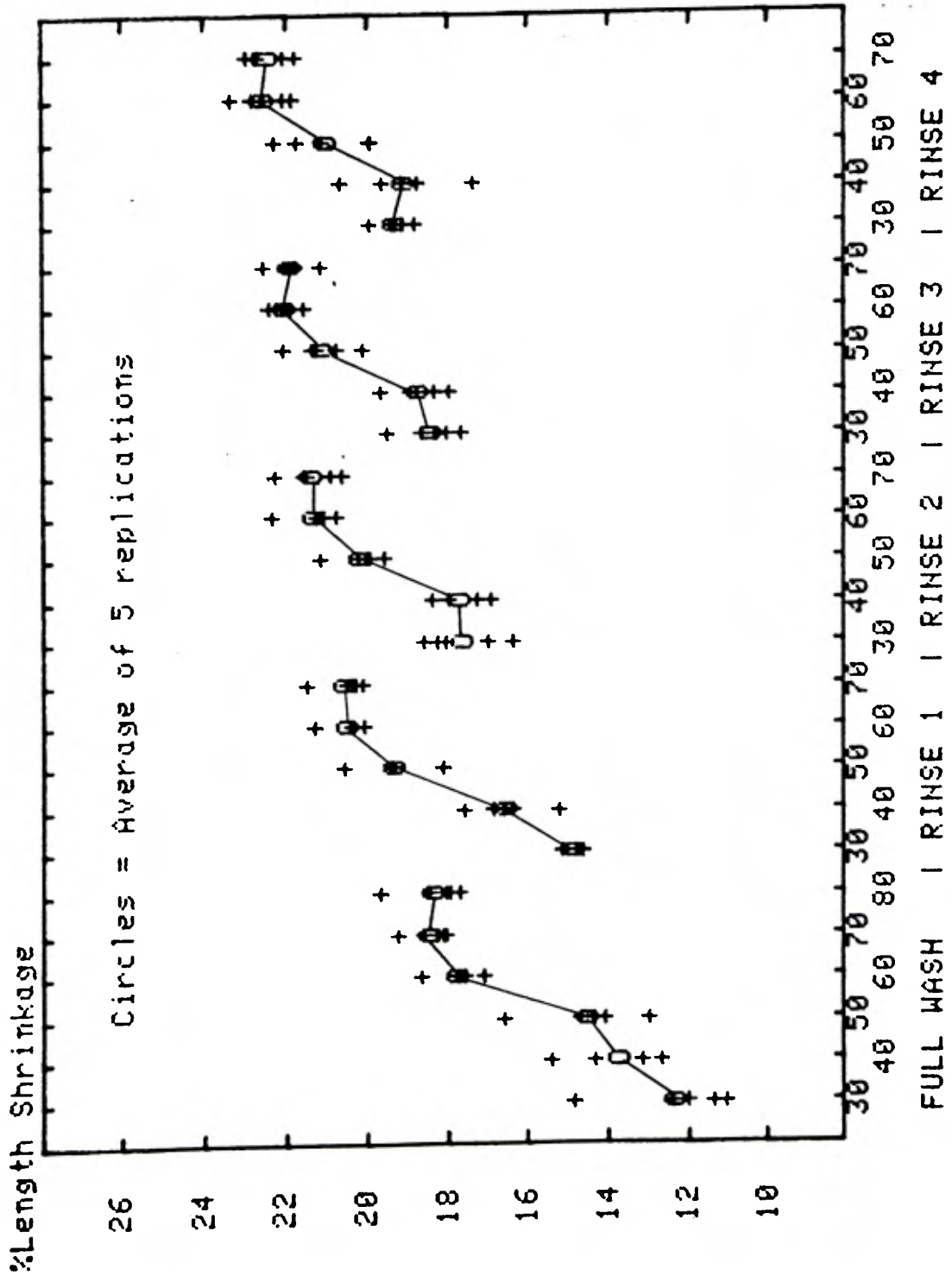
SHRINKAGE IN TUMBLE DRYING : SET 0 : ALL CYCLES



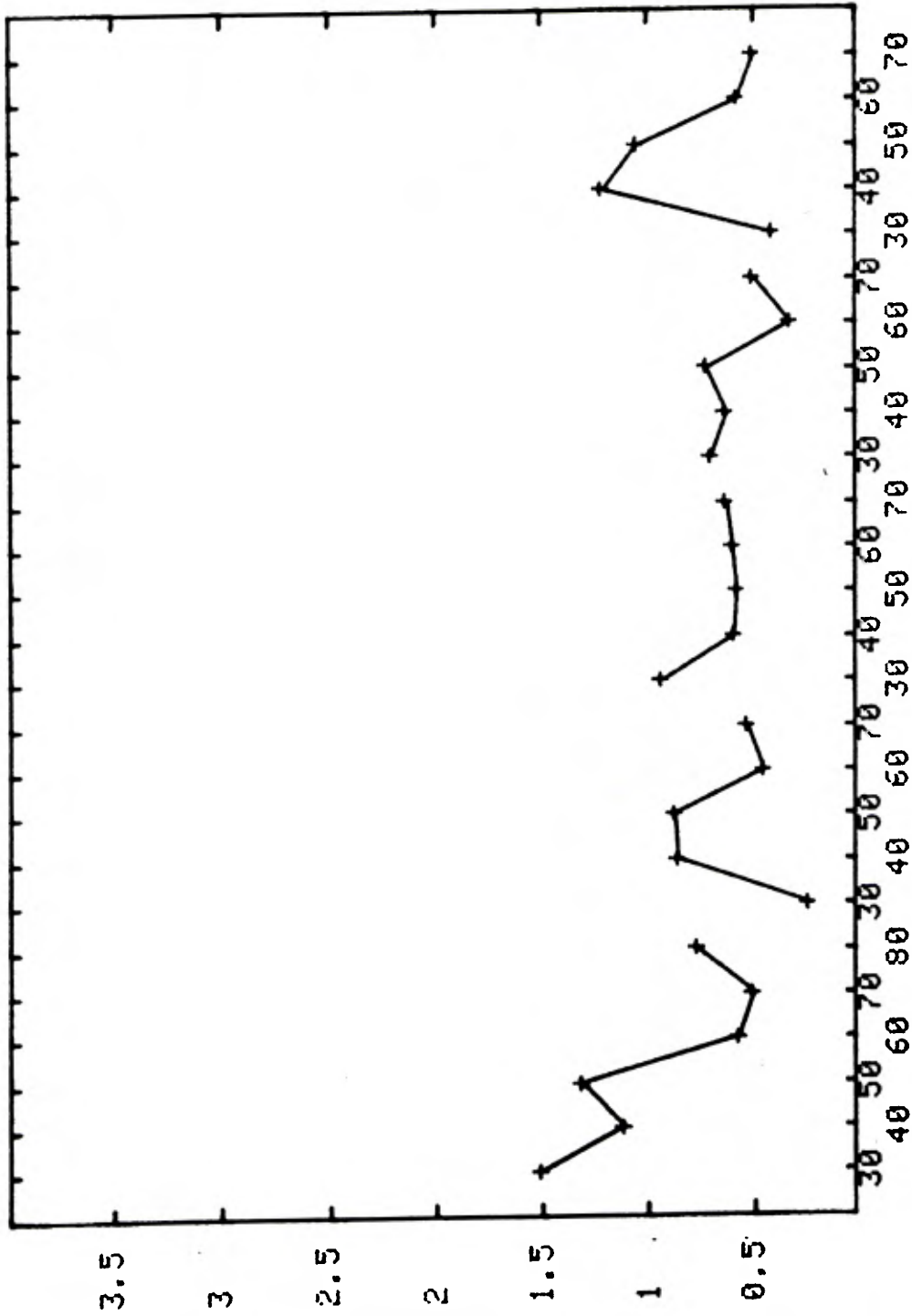
FULL WASH | RINSE 1 | RINSE 2 | RINSE 3 | RINSE 4  
Time in Tumble Dryer



SHRINKAGE IN TUMBLE DRYING : SET 0 : ALL CYCLES

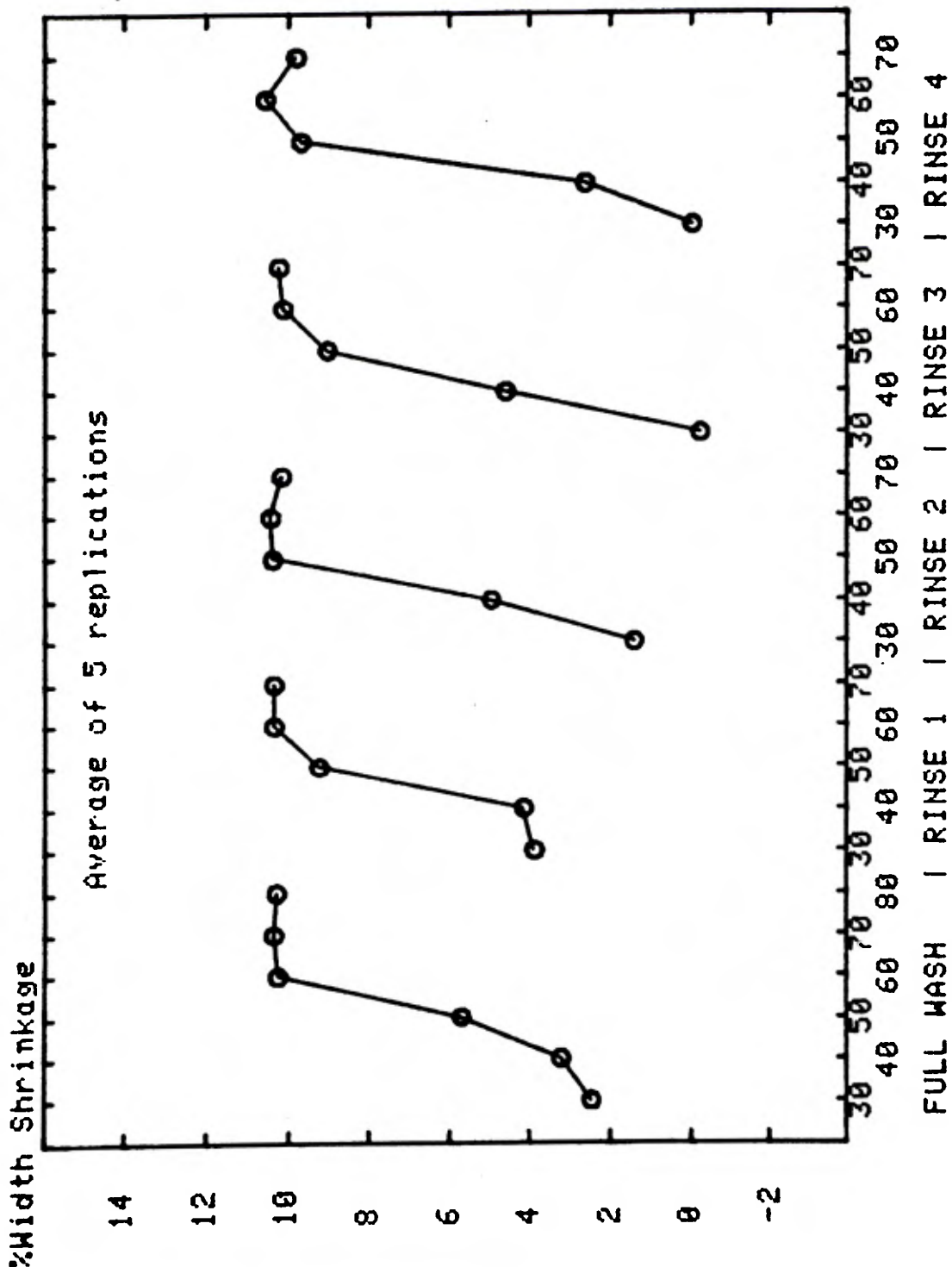


%LENGTH SHRINKAGE STANDARD DEVIATIONS

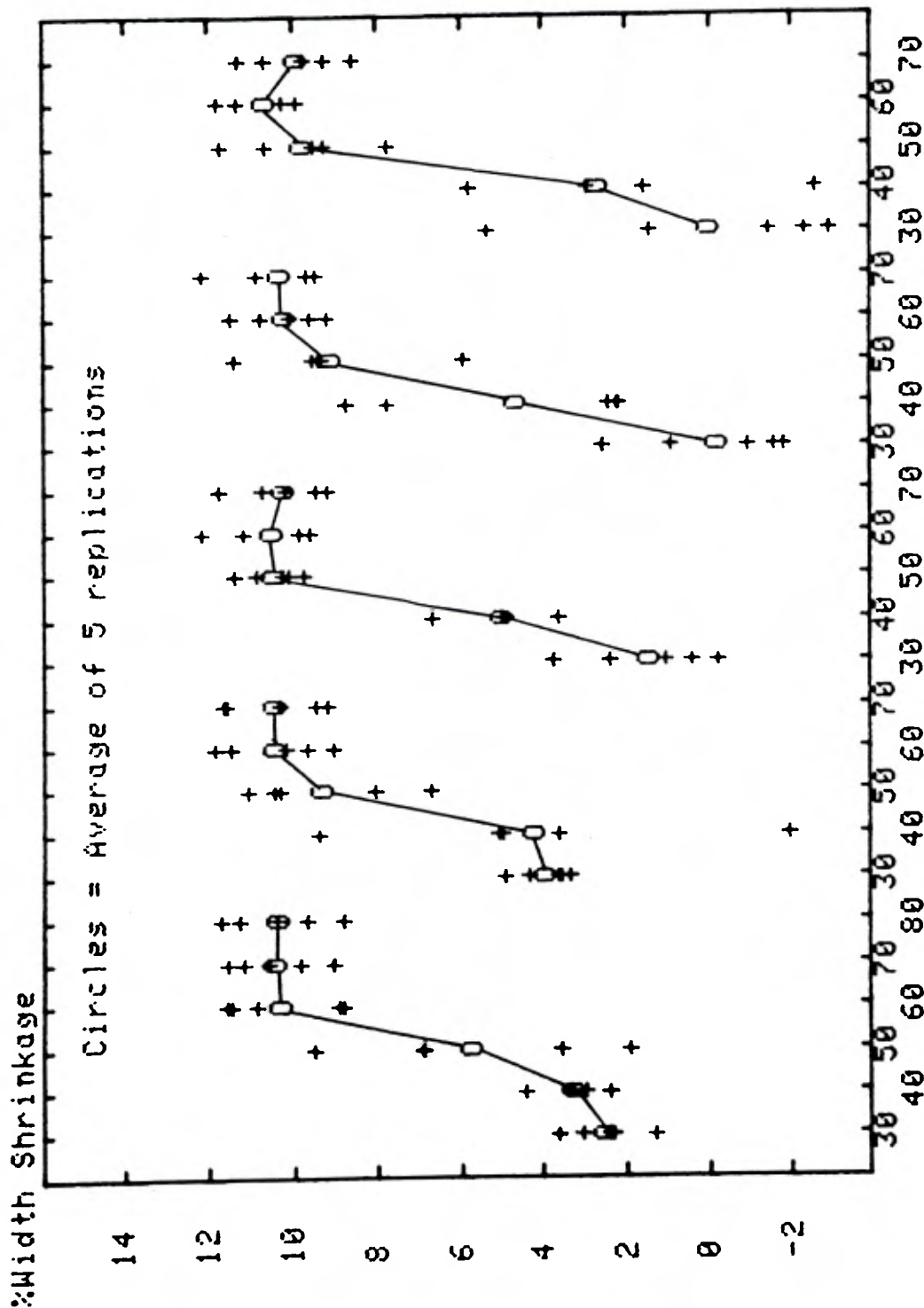


1st Cycle 12nd Cycle 13rd Cycle 14th Cycle 15th Cycle  
Time (mins) in Tumble Dryer

SHRINKAGE IN TUMBLE DRYING : SET 0 : ALL CYCLES



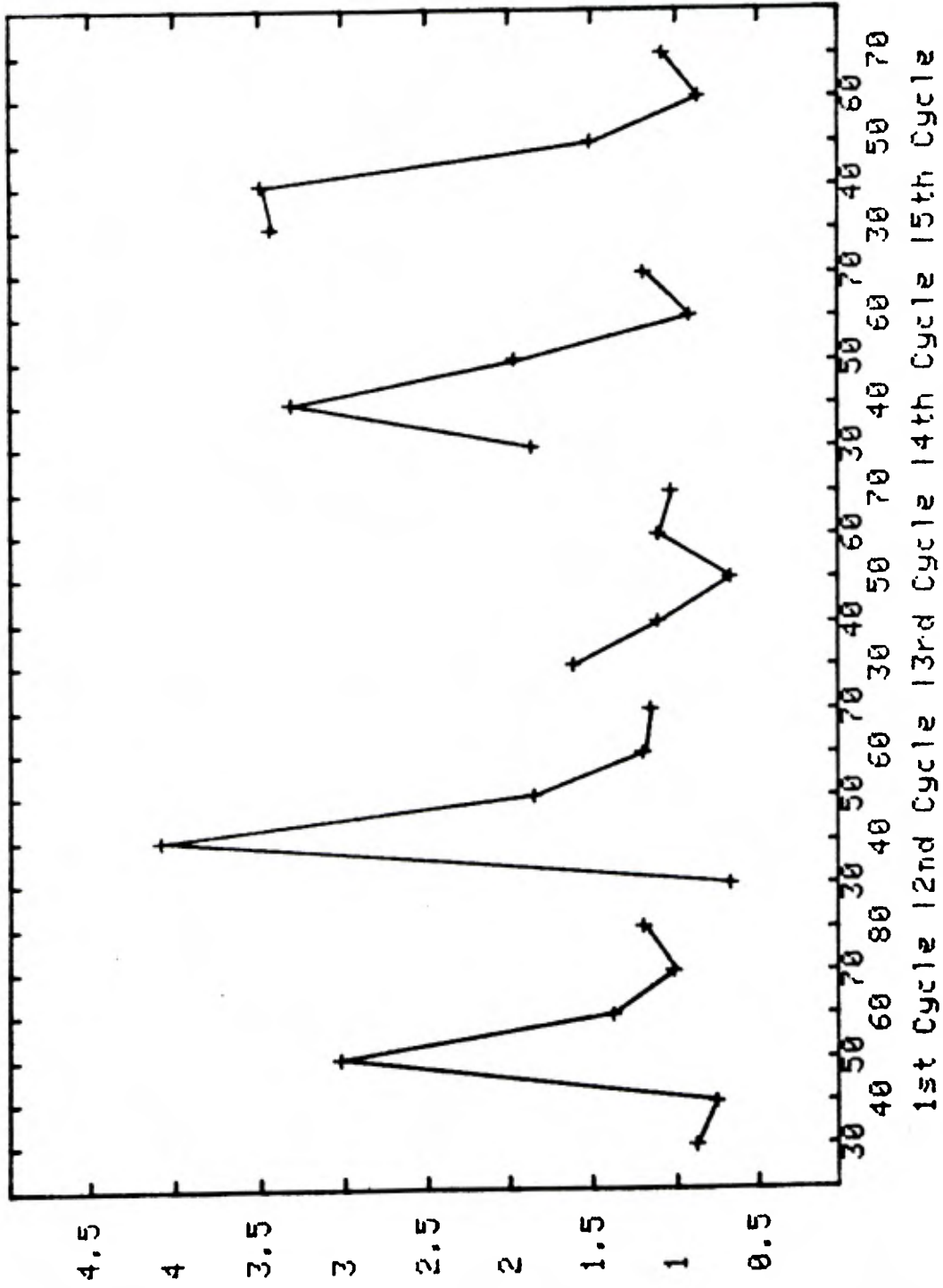
SHRINKAGE IN TUMBLE DRYING : SET 0 : ALL CYCLES



FULL WASH | RINSE 1 | RINSE 2 | RINSE 3 | RINSE 4

Time in Tumble Dryer (mins)

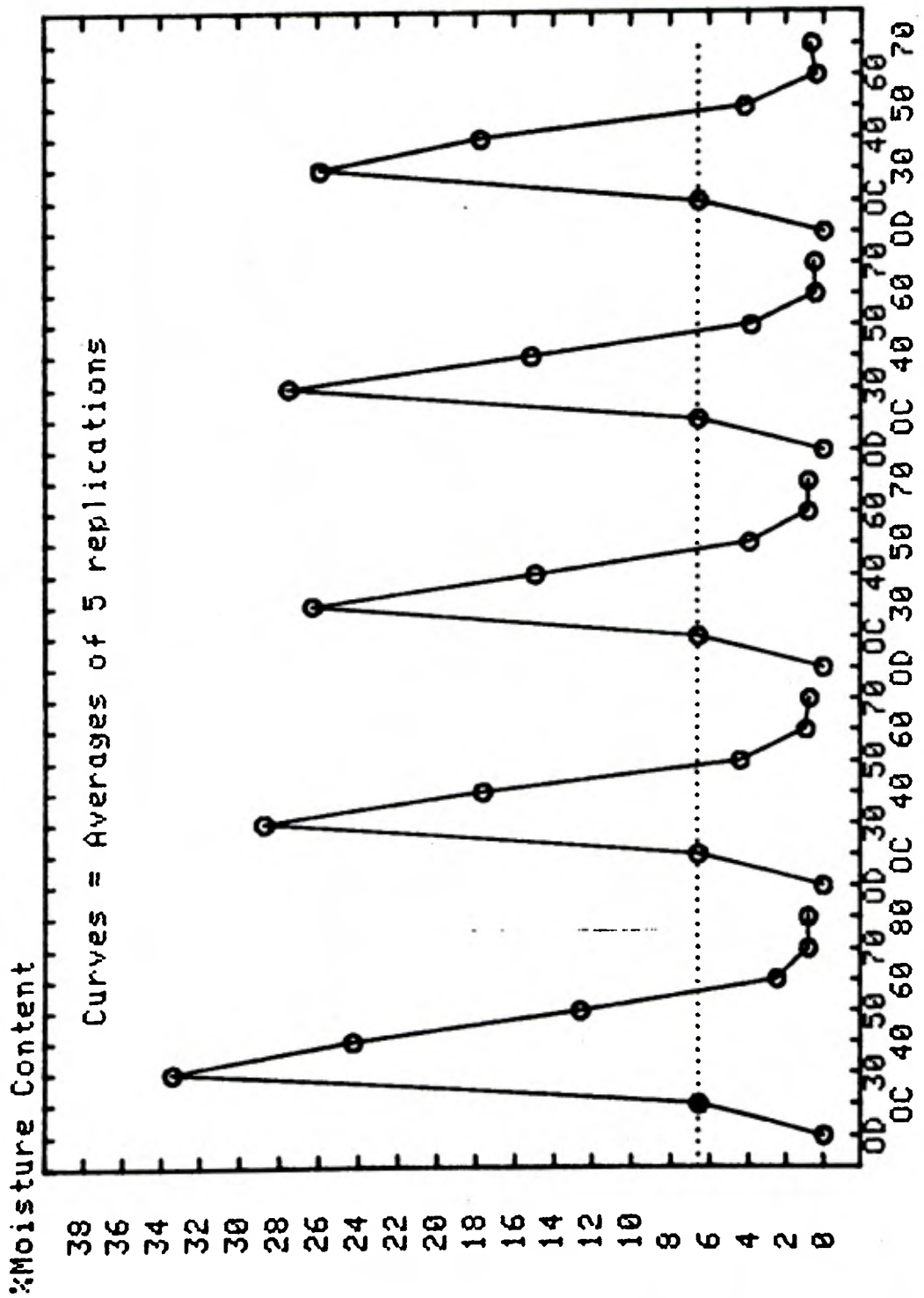
%WIDTH SHRINKAGE STANDARD DEVIATIONS



Time (mins) in Tumble Dryer

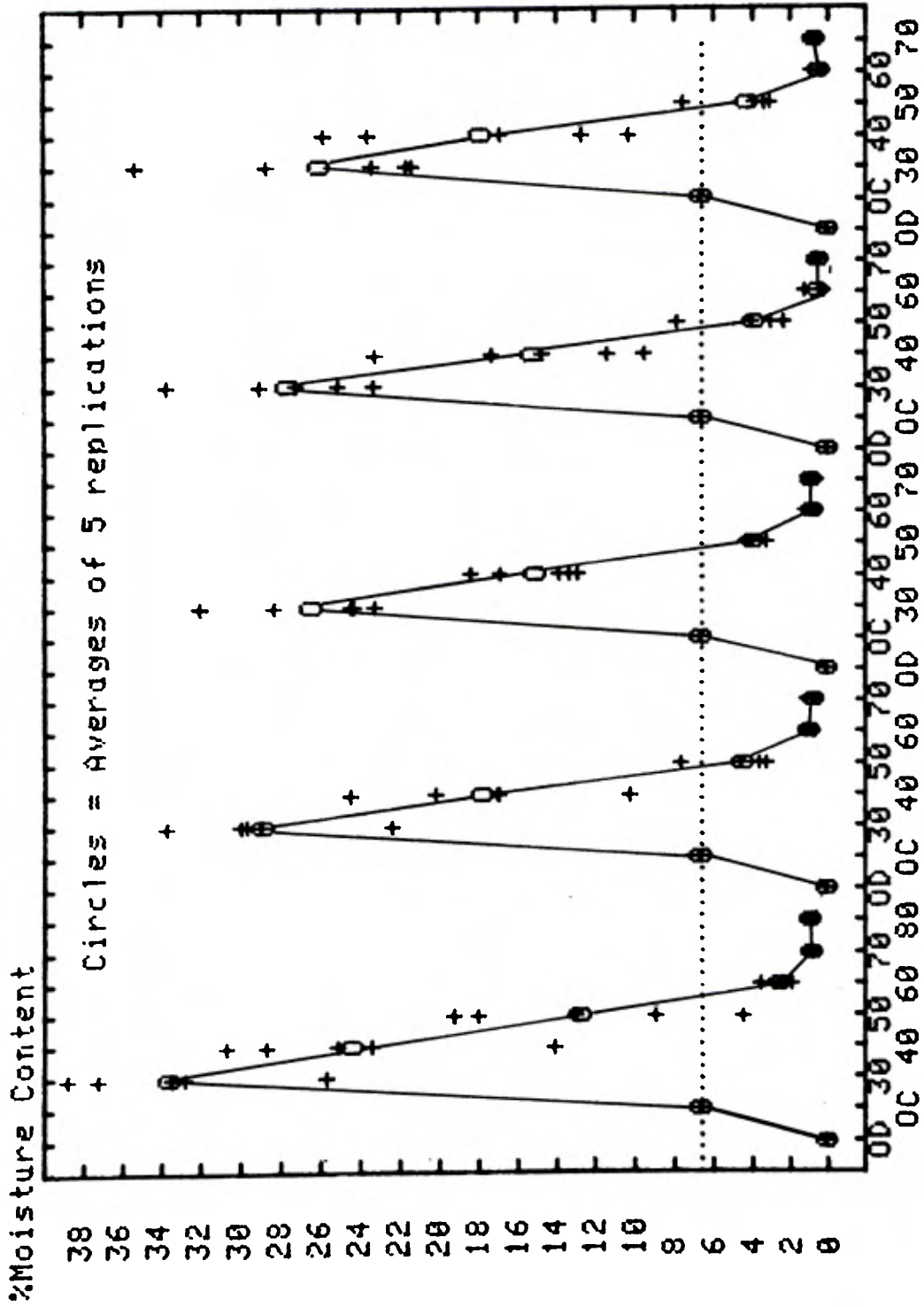
FIGURE 7

SHRINKAGE IN TUMBLE DRYING : SET 0 : ALL CYCLES



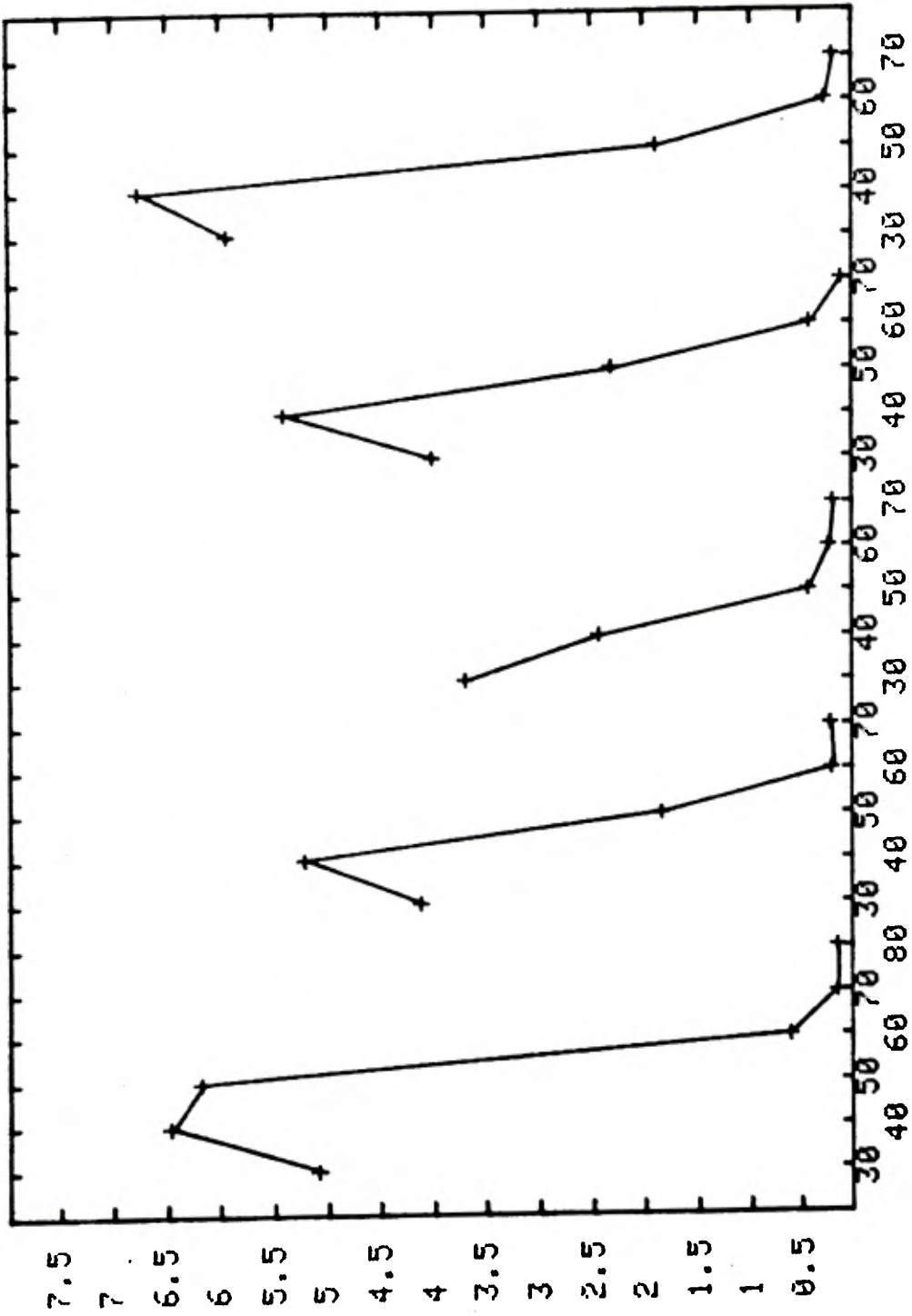
FULL WASH | RINSE 1 | RINSE 2 | RINSE 3 | RINSE 4  
Time in Tumble Dryer (mins)

SHRINKAGE IN TUMBLE DRYING : SET 0 : ALL CYCLES



FULL WASH | RINSE 1 | RINSE 2 | RINSE 3 | RINSE 4  
Time in Tumble Dryer (mins)

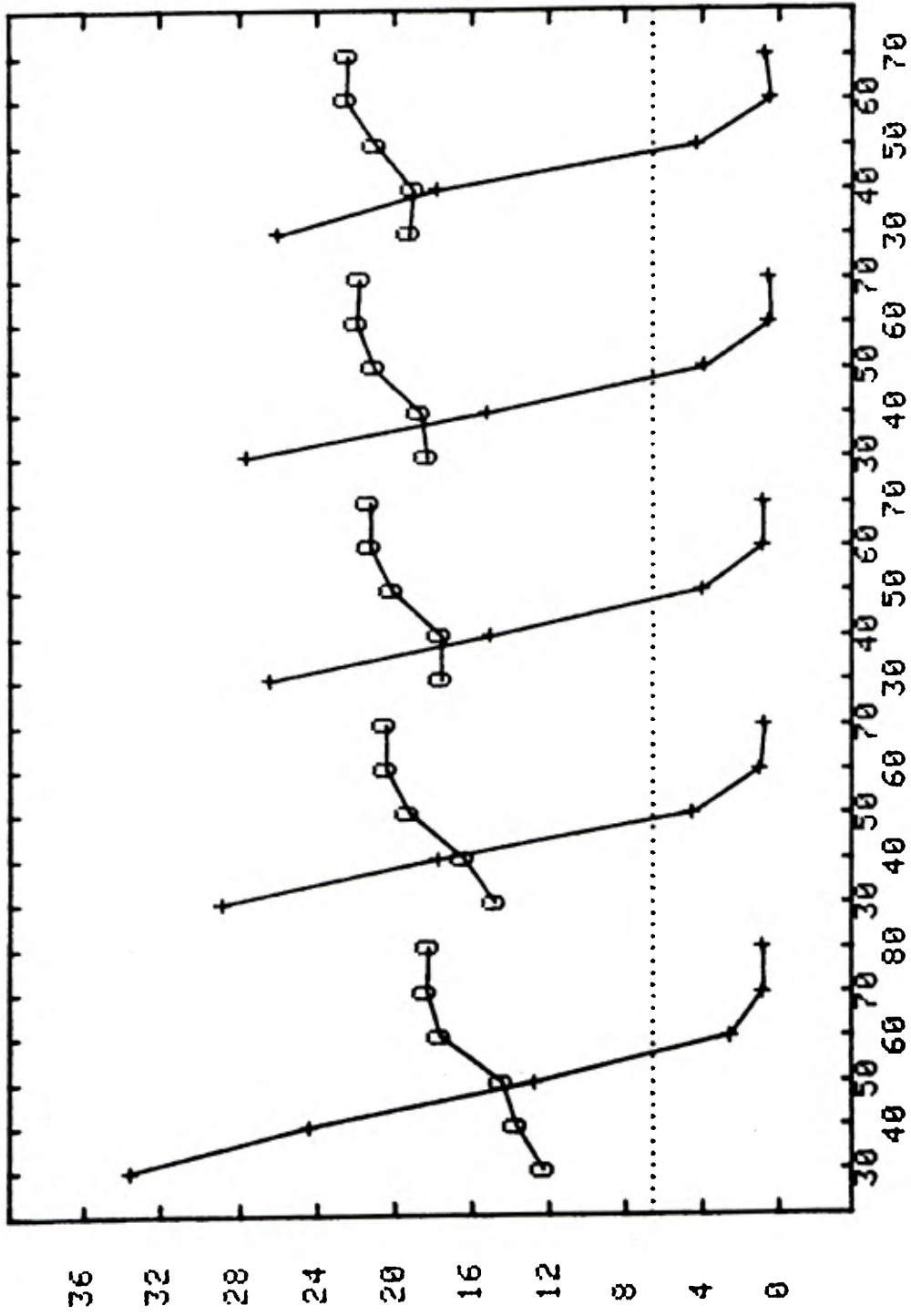
%MOISTURE CONTENT STANDARD DEVIATIONS



1st Cycle 12nd Cycle 13rd Cycle 14th Cycle 15th Cycle  
Time (mins) in Tumble Dryer

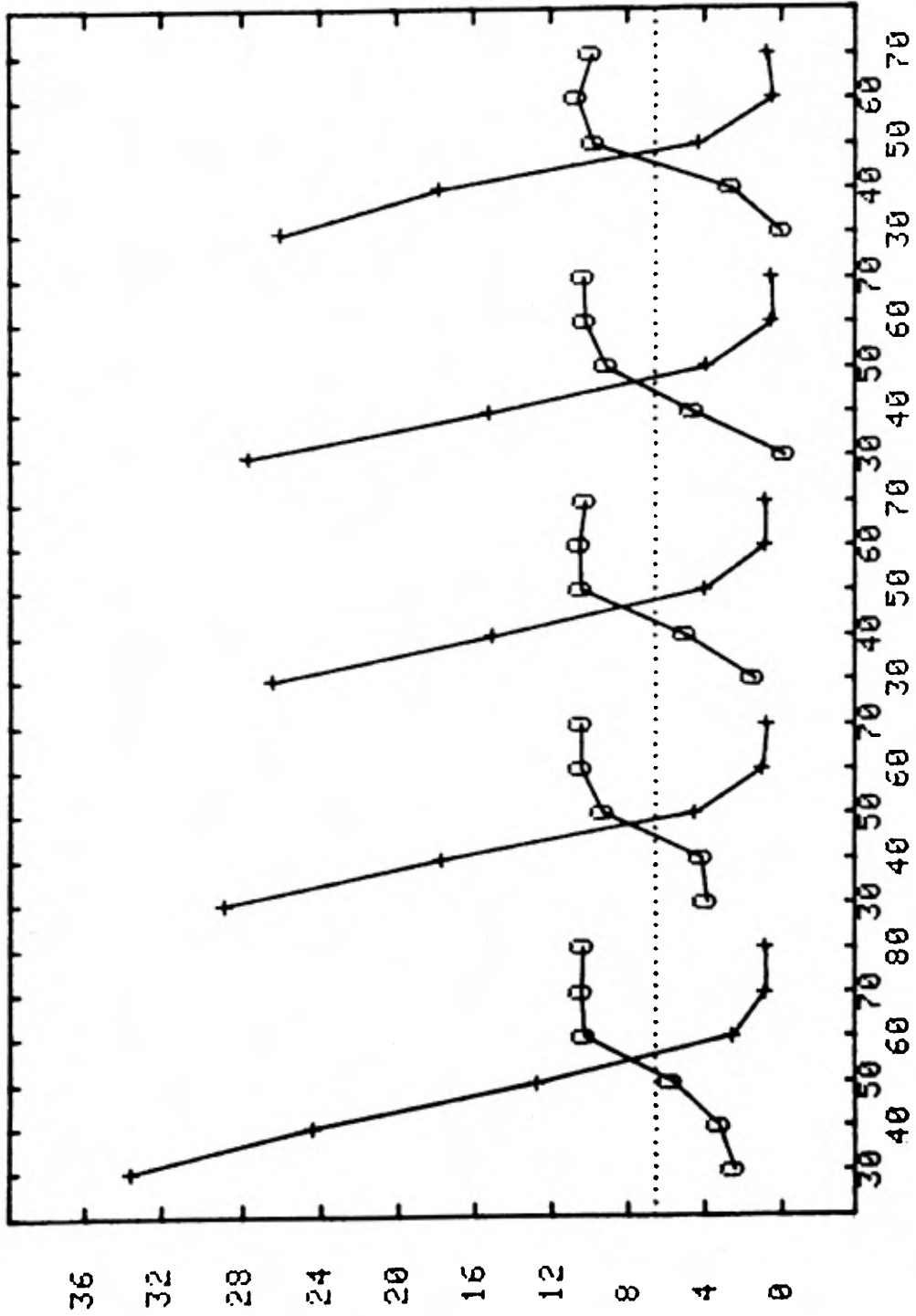


AVERAGE % MOISTURE CONTENT (+) / AVERAGE % LENGTH SHRINKAGE (O)



1st Cycle 12nd Cycle 13rd Cycle 14th Cycle 15th Cycle  
Time (mins) in Tumble Dryer

AVERAGE % MOISTURE CONTENT (+) / AVERAGE % WIDTH SHRINKAGE (O)



1st Cycle 12nd Cycle 13rd Cycle 14th Cycle 15th Cycle  
Time (mins) in Tumble Dryer