

CHAPTER IV

RESULTS AND DISCUSSION

Preliminary Data of Fabric Used

In the study a scoured white cotton fabric weighing 2.47 oz./yd² (84.8 gm/m²) with yarn count of 120 x 106 per inch (48 x 42 per cm.) and thickness of 0.003 inch (0.012 cm) was used.

In the earlier work carried out in the clothing and textile department, with which the present author was also connected, the formaldehyde along with commonly used hydroxy compounds like, starch, carboxy-methyl cellulose (C.M.C.) were used to find out whether these hydroxy compounds can react with formaldehyde and give improved properties. Nonita (24) has reported that starch and carboxy methyl cellulose compounds lowered wrinkle recovery, although some loss in strength was observed. This was attributed to the increased stiffness due to the film forming nature of starch and carboxy methyl cellulose.

While in the other work conducted in the department and reported by Pandya (27) starch, polyethylene glycols and polyvinyl alcohol were used along with urea-formaldehyde resin. Starch and polyvinyl alcohol alongwith urea-formaldehyde cured at 140°C showed decreased wrinkle recovery similar to above

study (24). This was also attributed to the film forming nature of starch and polyvinyl alcohol compounds. Polyethylene glycol with urea-formaldehyde also did not show any improvement in wrinkle recovery. Since there were variations in the recovery and strength loss, no positive conclusions were reported.

As already mentioned, since the reaction of ethylene glycol type polyhydroxy compounds was not concluded due to variations observed under the normal conditions of curing. Experimental trials of a few of these samples were recured at higher temperature, there was no further loss in strength but wrinkle recovery was improved. Hence it was therefore to see whether ethylene glycol compounds are sensitive to these temperature - Since normally 160°C also used for curing some of the resins.

The influence of ethylene glycol type polyhydroxy compounds along with melamine formaldehyde on the physical properties of cotton fabric have been reported in Part I and formaldehyde analysis in Part II.

Part I : Influence of polyhydroxy compounds alongwith melamine formaldehyde resin on the physical properties of cotton.

1. Effect of polyhydroxy compounds alongwith melamine formaldehyde resin on wrinkle recovery.
2. Effect of polyhydroxy compounds alongwith melamine formaldehyde resin on tensile strength and elongation.

1. Effect of Polyhydroxy Compounds alongwith Melamine Formaldehyde Resin on Wrinkle Recovery.

The finished fabric samples at different treatments were cured at varying conditions and the data on wrinkle recovery have been reported in Table 2 and represented in Figure 1.

The usual improvement in wrinkle recovery was observed with the treatments, in general, higher effects with higher temperature (160°C) as compared to the effect of lower temperature (140°C). Specific mention is however made of the positive influence of polyethylene glycol- 400 along with melamine formaldehyde (T_{3MF}) at 160°C . This improvement in wrinkle recovery was substantial and specific nature of this is attributed to a possible reaction mechanism of polyethylene-glycol itself giving independent or separate linkages.

It will be of interest to see whether these improvements in wrinkle recovery have any deterioration effect on the strength of the fabric. This is reported in the next section of the study.

2. Effect of Polyhydroxy Compounds along with Melamine Formaldehyde Resin on Tensile Strength and Elongation

The data on changes in tensile strength of finished samples have been given in Table 3, and represented in Figure 2.

TABLE 2

WRINKLE RECOVERY (°) OF FINISHED FABRICS AT
DIFFERENT CURING CONDITIONS (EFFECT OF TEMPE-
RATURE ON CURING)

Treatment	Curing Conditions			Wrinkle Recovery (°)		
	Temp.:	140°C	140°C	140°C	160°C	160°C
	Time : (min.)	5	10	5	5	5
T _{MF}		212	215	231		
T _{1MF}		212	213	255		
T _{2MF}		220	242	252		
T _{3MF}		240	250	275		
(Wrinkle recovery (°) of unfinished = 182)						

- T_{MF} - MF
T_{1MF} - MF + Diethylene glycol
T_{2MF} - MF + Polyethylene glycol - 200
T_{3MF} - MF + Polyethylene glycol - 400
(MF - Melamine formaldehyde)

FIG. I. EFFECT OF DIFFERENT CURING CONDITIONS ON WRINKLE RECOVERY (°) OF FINISHED FABRIC AT DIFFERENT TREATMENTS.

T₀ - Unfinished

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF = Melamine formaldehyde)

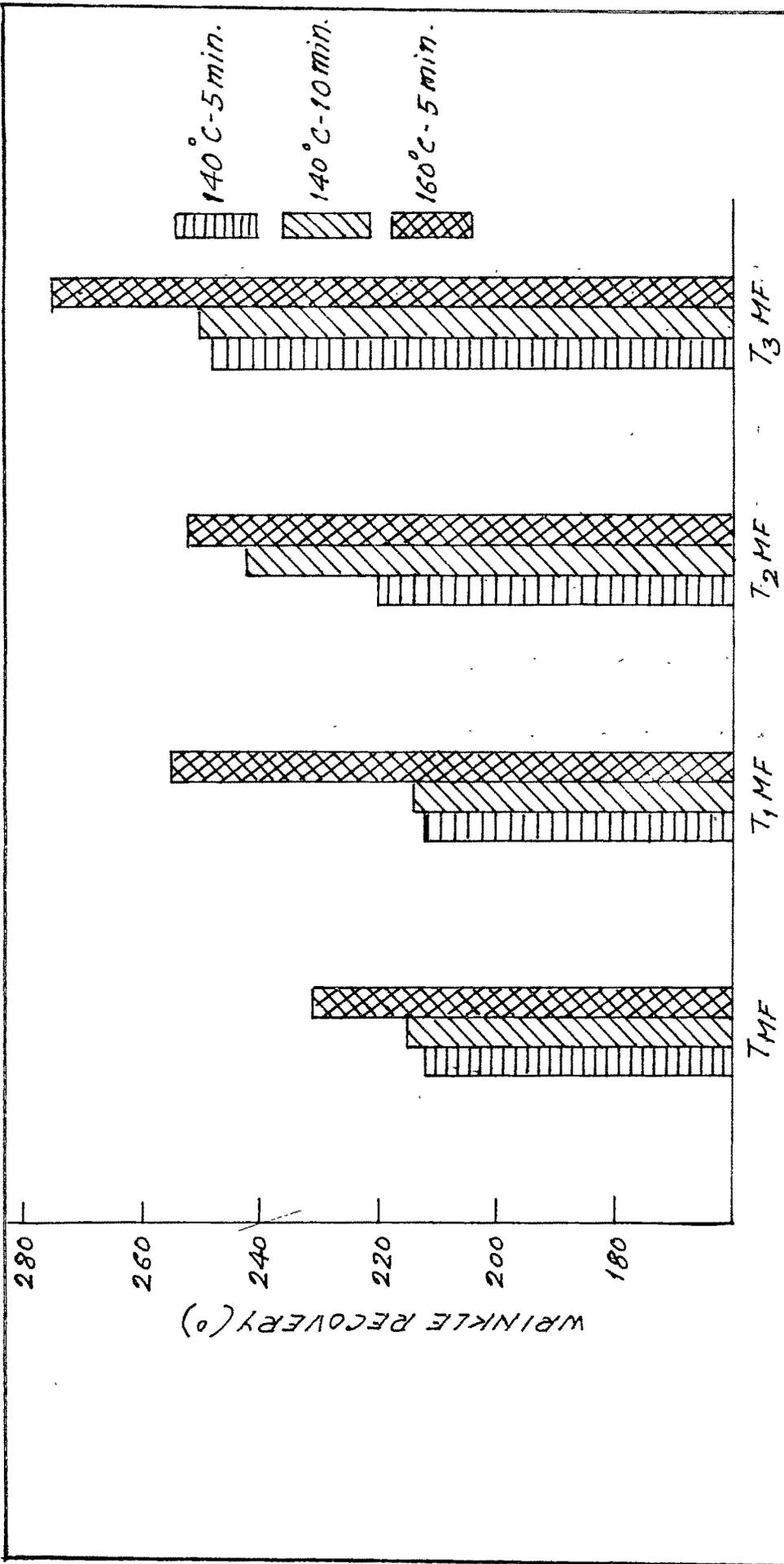


FIG. 1

EFFECT OF DIFFERENT CURING CONDITIONS ON
WRINKLE RECOVERY (%) OF FINISHED FABRICS AT
DIFFERENT TREATMENTS

TABLE 3

TENSILE STRENGTH OF FINISHED FABRICS AT DIFFERENT TREATMENTS

Treatment	Tensile Strength (lbs)
To	34.5
T _{MF}	26.1
T _{1MF}	26.0
T _{2MF}	25.0
T _{3MF}	24.8

To - Unfinished fabric
T_{MF} - MF
T_{1MF} - MF + Diethylene glycol
T_{2MF} - MF + Polyethylene glycol - 200
T_{3MF} - MF + Polyethylene glycol - 400
(MF - Melamine formaldehyde)

FIG. 2 . EFFECT OF DIFFERENT TREATMENTS ON
WRINKLE RECOVERY (°) AND TENSILE STRENGTH(lbs)
OF FINISHED FABRIC.

T₀ - Unfinished

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF = Melamine formaldehyde)

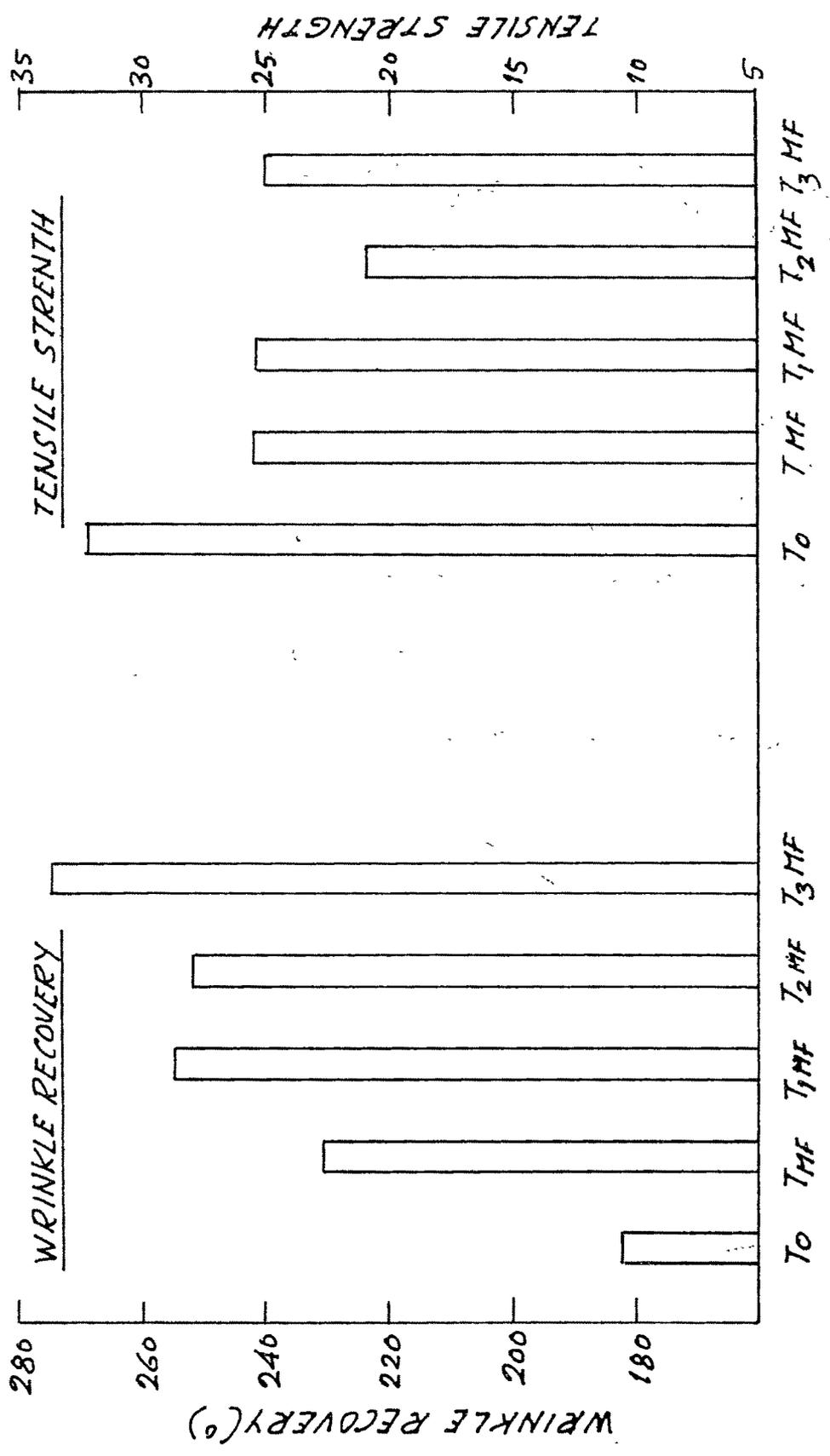


FIG. 2

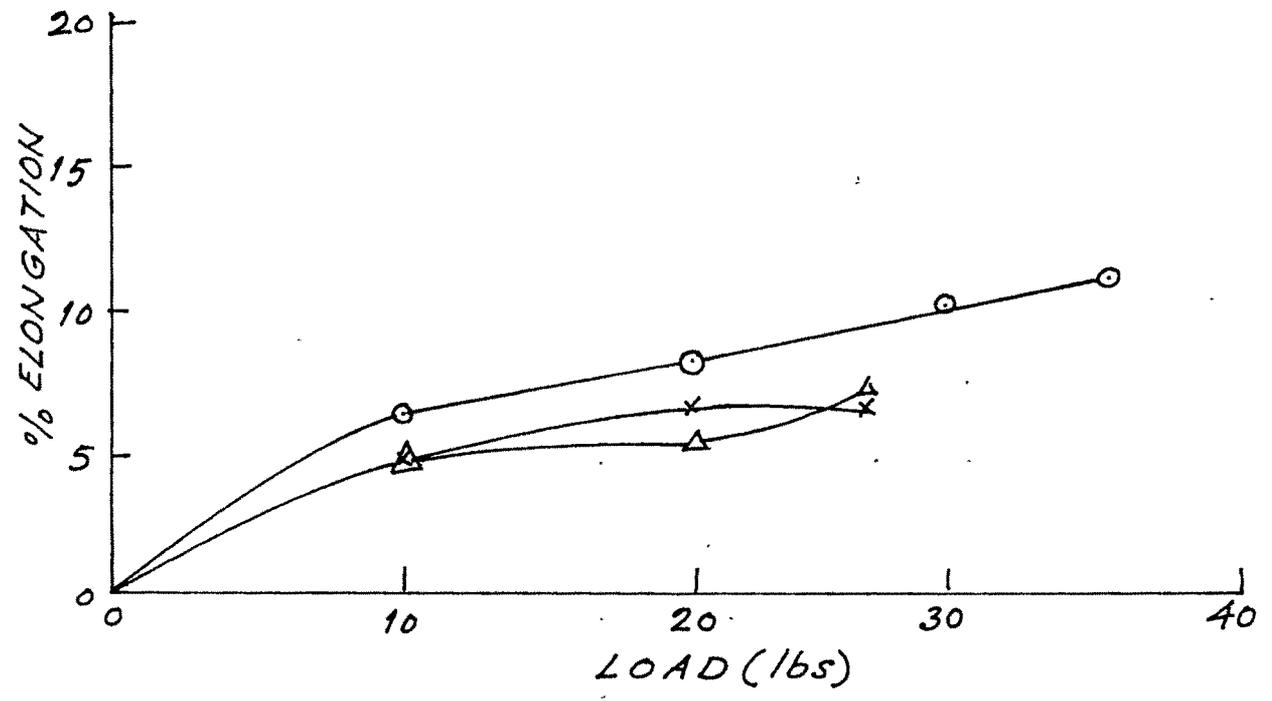
EFFECT OF DIFFERENT TREATMENTS ON WRINKLE RECOVERY(%) AND TENSILE STRENGTH(LBS) OF FINISHED FABRICS

TABLE 4
 PERCENTAGE ELONGATION AT VARYING LOADS OF
 FINISHED FABRICS AT DIFFERENT TREATMENTS

Treatment	Load (lbs)	Percent Elongation		
		10	20	at Breaking load
T ₀		6.6	8.3	14.7(34.5 lbs)
T _{MF}		5.0	6.6	8.7(26.1 lbs)
T _{1MF}		5.0	5.8	9.6(26.0 lbs)
T _{2MF}		2.5	5.0	7.0(25.0 lbs)
T _{3MF}		2.5	5.0	6.6(24.8 lbs)

(Number shown in brackets is breaking load)

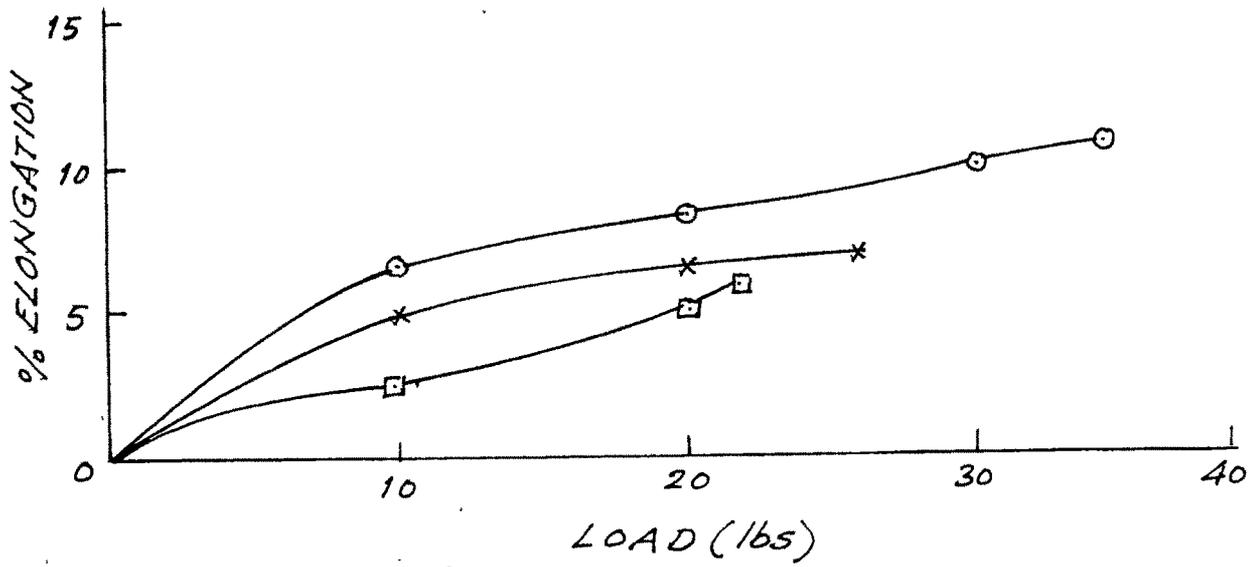
- T₀ - Unfinished
 T_{MF} - MF
 T_{1MF} - MF + Diethylene glycol
 T_{2MF} - MF + Polyethylene glycol - 200
 T_{3MF} - MF + Polyethylene glycol - 400
 (MF - Melamine formaldehyde)



- T₀ - UNTREATED
- X—X T_{MF} - MF
- △—△ T₁, MF - MF + DIETHYLENE GLYCOL
(MF = MELAMINE FORMALDEHYDE)

FIG. 3(a)

PERCENTAGE ELONGATION VS LOAD OF FINISHED
FABRICS AT DIFFERENT TREATMENTS



- T₀ - UNTREATED
- x—x T₁ MF-MF
- T₂ MF-MF + POLYETHYLENE GLYCOL-200
- T₃ MF-MF + POLYETHYLENE GLYCOL-400

FIG. 3 (b)

PERCENTAGE ELONGATION VS LOAD OF FINISHED FABRICS AT DIFFERENT TREATMENTS

Melamine formaldehyde treated samples (T_{MF}) have shown considerable loss of strength (26.1 lbs) compared to unfinished fabric (34.5 lbs). Melamine formaldehyde samples have shown reduced elongation at break (8.7%) compared to unfinished fabric (11.7%). Table 4 .

No specific differences in strength and elongation in the finished samples at breaking point were noticed. Melamine formaldehyde samples have shown lower elongation at intermediate loads compared to un-finished fabric samples (Figure 3 a, b). With polyethylene glycols along with melamine formaldehyde (T_{2MF} , T_{3MF}) higher differences in elongation at intermediate loads were noticed. The differences in elongation at intermediate loads have been attributed to reaction mechanism of polyhydroxy compounds, the reaction being higher with polyethylene glycol - 400 (T_{3MF}) as seen by the lowering of curves. Such changes in the load-elongation curve are usually explained as restrictions caused by the polymerization - crosslinking (19). These reaction mechanisms have been discussed later after the analysis of formaldehyde.

PART II

Analysis of Formaldehyde Content of
Different Finishing Treatments

In the part I of the study the effect of different finishing treatments on physical properties of cotton were studied. The results indicated a positive influence of polyhydroxy compounds on wrinkle recovery without further loss of strength and elongation. This was attributed to a possible, separate, reaction of polyhydroxy compounds. One of the possible chemical reaction being the reaction of formaldehyde, released/ loosely held with glycols resulting in acetal resin during finishing treatments as reported by Marsh (19) and Ranney (20). Formaldehyde thus could exist in varying reacted/loosely held forms. The analysis of formaldehyde was carried out to see the contents of the same.

1. Effect of Different Finishing Treatments on
the Free and Total Formaldehyde Content of
Fabric.

The data on free and total formaldehyde of cured samples at different finishing treatments have been given in Table 5 and represented in Figure 4. The free formaldehyde would indicate the extent of properly reacted melamine formaldehyde (with/without polyhydroxy compounds). Samples treated with polyhydroxy compounds in general have shown lower levels of free formaldehyde compared to melamine formaldehyde alone treated samples. This indicated greater degree of reaction,

TABLE 5

ANALYSIS OF FREE AND TOTAL FORMALDEHYDE FROM FINISHED FABRICS AT DIFFERENT TREATMENTS.

Treatment	Free - Formaldehyde (PPM)	Total Formaldehyde (Washed Sample) (PPM)	App. Total Formaldehyde (Unwashed) (PPM)
T _{MF}	4,150	16,000	21,150
T _{1MF}	3,500	20,000	23,500
T _{2MF}	3,200	21,000	24,200
T _{3MF}	3,100	24,000	27,100

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF - Melamine formaldehyde)

FIG. 4. FORMALDEHYDE CONTENT OF FINISHED
AT DIFFERENT TREATMENTS.

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol- 400

(MF = Melamine formaldehyde.)

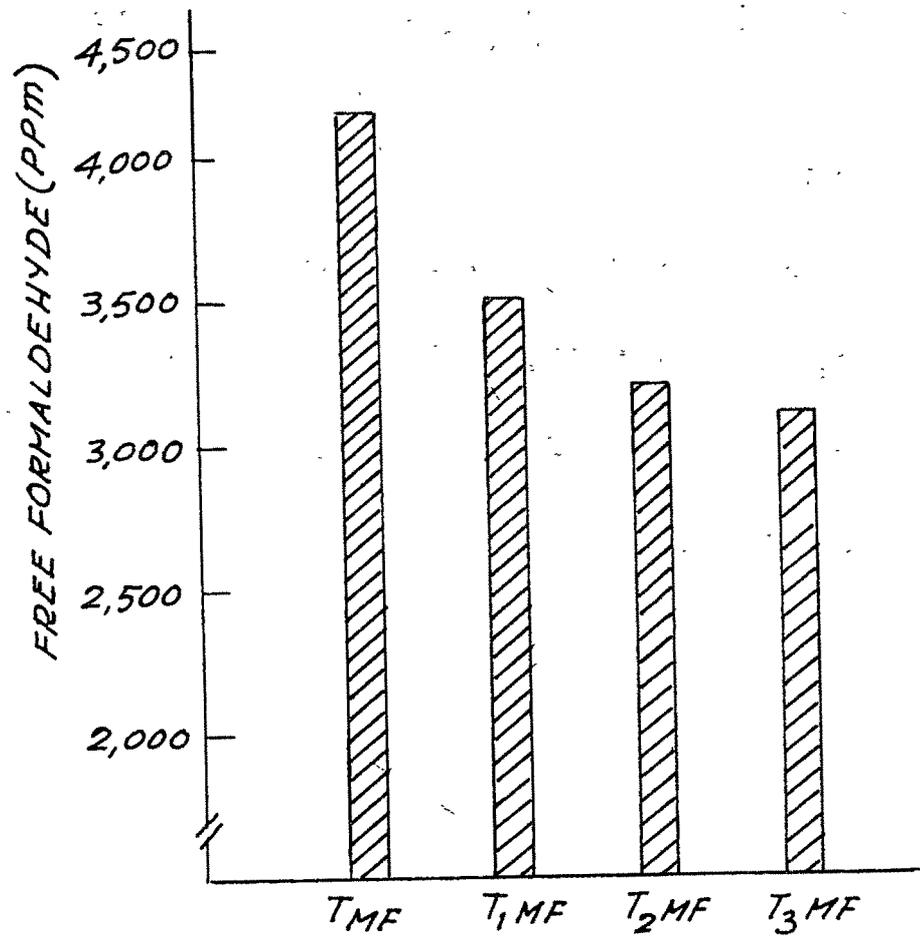


FIG. 4

FREE FORMALDEHYDE CONTENT OF FINISHED
FABRICS AT DIFFERENT TREATMENTS

FIG. 5. RELATION BETWEEN TOTAL AND LIBERATED
FORMALDEHYDE OF FINISHED FABRIC AT DIFFERENT
TREATMENTS.

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF = Melamine formaldehyde)

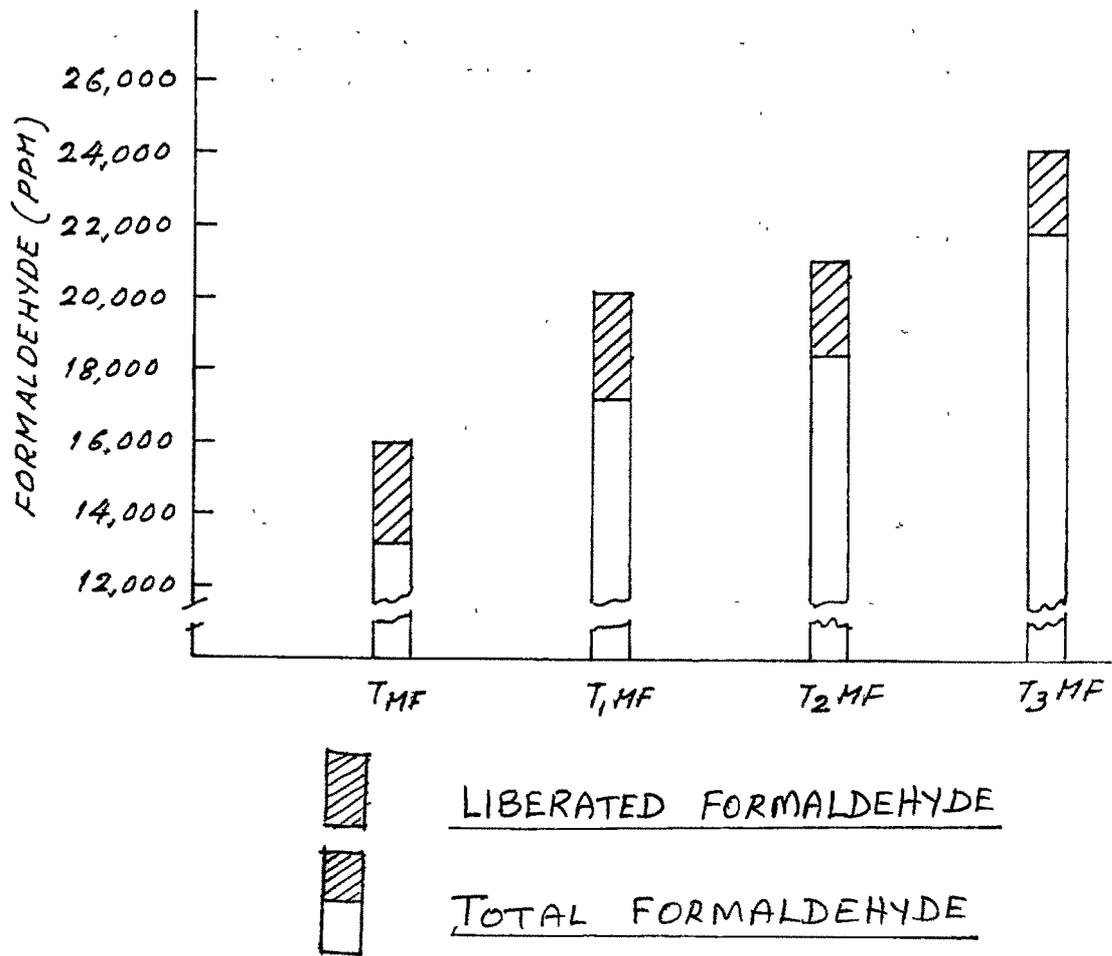
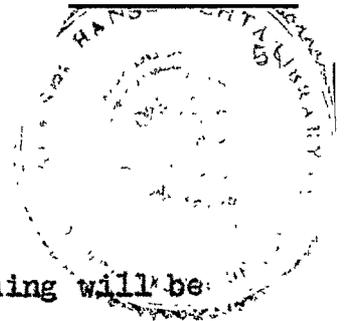


FIG. 5

RELATIONSHIP BETWEEN TOTAL AND LIBERATED FORMALDEHYDE OF FINISHED FABRICS AT DIFFERENT TREATMENTS



in other words, the total formaldehyde after washing will be higher. From the results of total formaldehyde analysis it is seen that total formaldehyde is considerably higher in the presence of polyhydroxy compounds in comparison to melamine formaldehyde alone treated samples. This supports the conclusion that the extent of reacted or bound formaldehyde was more in the presence of polyhydroxy compounds, especially it is specifically noticed in presence of polyethylene glycol-400 (T_{3MF}).

2. Effect of Different Finishing Treatments on the Liberated and Total Formaldehyde Content of Fabric

The data on liberated and total formaldehyde of finished samples at different treatments have been given in Table 6 and represented in Figure 4. From the data on percent liberated formaldehyde, given in the above table, it is concluded that in general formaldehyde liberation is reduced in the presence of polyhydroxy compounds. Considerable decrease in the liberated formaldehyde has been noticed with samples treated with polyethylene glycol-400 along with melamine formaldehyde (T_{3MF} - 9.5 percent), compared to melamine formaldehyde alone treated samples (T_{MF} - 17.5 percent).

Relationship Between Wrinkle Recovery and Percent Formaldehyde of Finished Fabrics at Different Treatments

The data on wrinkle recovery and percent formaldehyde have been given in Table 7 and represented in Figure 6.

TABLE 6

ANALYSIS OF FORMALDEHYDE, TOTAL AND LIBERATED
FROM FINISHED FABRICS AT DIFFERENT TREATMENTS.

Treatment	Formaldehyde		% Liberated Formaldehyde = $\frac{b}{a} \times 100$
	(a) Total (PPM)	(b) Liberated (PPM)	
T _{MF}	16,000	2,800	17.5
T _{1MF}	20,000	2,800	14.0
T _{2MF}	21,000	2,700	13.1
T _{3MF}	24,000	2,300	9.5

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF - Melamine formaldehyde)

TABLE 7

RELATIONSHIP BETWEEN WRINKLE RECOVERY (°)
AND PERCENT FORMALDEHYDE OF FINISHED FABRICS
AT DIFFERENT TREATMENTS.

Treatment	Wrinkle Recovery (°)	% Formaldehyde
T _{MF}	231	1.6
T _{1MF}	255	2.0
T _{2MF}	252	2.1
T _{3MF}	275	2.4

(Wrinkle recovery (°) of original is 182)

- T_{MF} - MF
- T_{1MF} - MF + Diethylene glycol
- T_{2MF} - MF + Polyethylene glycol - 200
- T_{3MF} - MF + Polyethylene glycol - 400

(MF - Melamine formaldehyde)

FIG. 6. RELATIONSHIP BETWEEN WRINKLE RECOVERY (°) AND PERCENT FORMALDEHYDE OF FINISHED FABRICS AT DIFFERENT TREATMENTS

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF = Melamine formaldehyde)

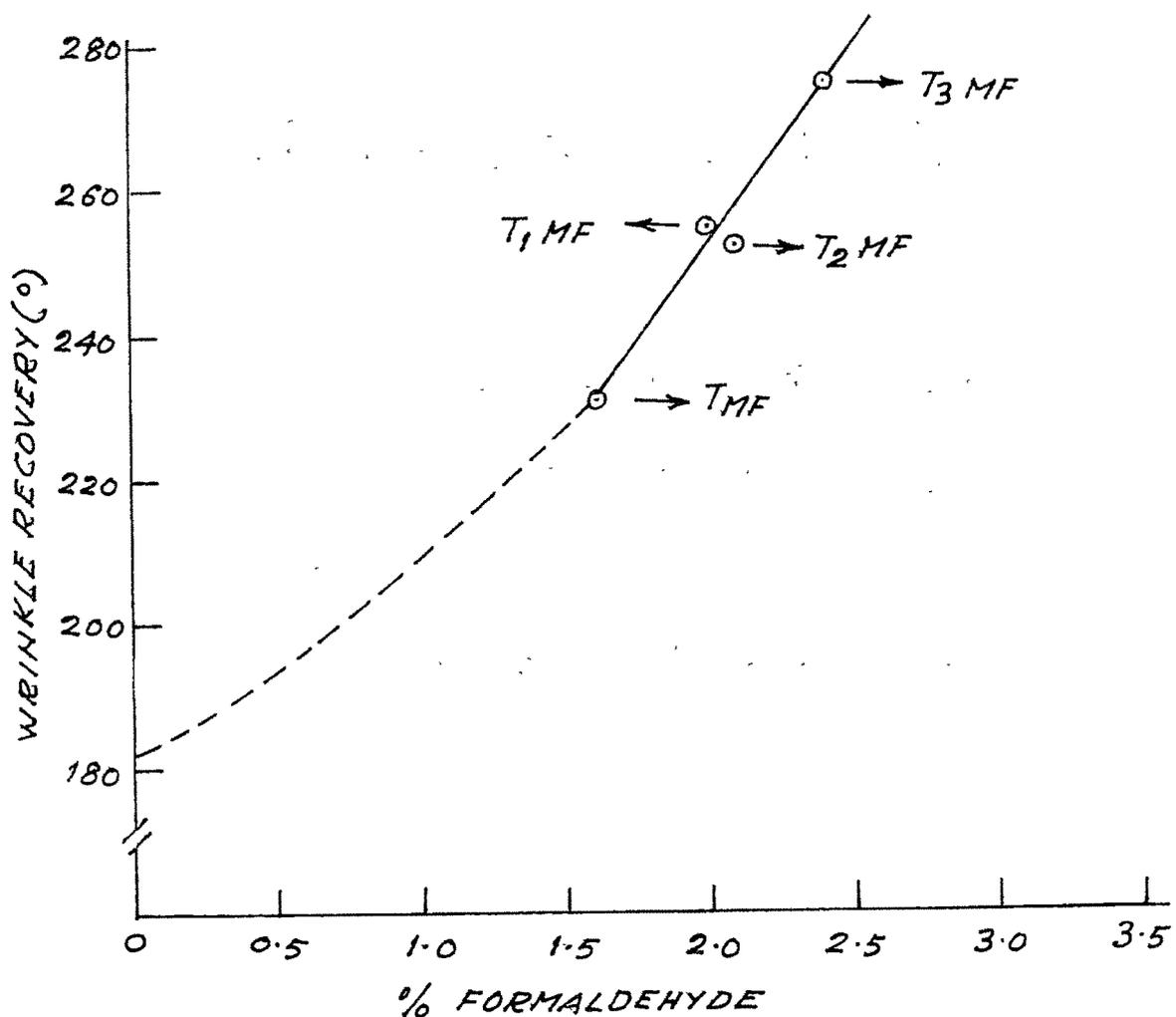


FIG. 6

RELATIONSHIP BETWEEN WRINKLE RECOVERY (%) AND
PERCENT FORMALDEHYDE OF FINISHED FABRICS AT
DIFFERENT TREATMENTS

Wrinkle recovery increased gradually with increase in percent formaldehyde, this increase was seen more specific with treatments involving polyethylene glycol compounds (using the latter part of the curve in Figure 6). The results further indicated that polyethylene glycol compounds has retained more formaldehyde by chemical reaction, thus improving recovery.

Relationship Between Tensile Strength and Percent Formaldehyde of Finished Fabrics at Different Treatments

The data on tensile strength and percent formaldehyde have been given in Table 8 and represented in Figure 7. As expected with resin finish there was loss of strength with the finishing treatments. However the treatments containing polyethylene glycol compounds along with melamine formaldehyde did not show further loss in strength as seen from latter part of the curve in spite of more percent formaldehyde. Thus it was observed that the formaldehyde which was held in presence of polyethylene glycol compounds, not only improved wrinkle recovery (as mentioned on page 53) but it also helped in not causing further loss in strength. This led to the possibility of formaldehyde being held differently in presence of polyhydroxy compounds.

Relationship Between Wrinkle Recovery and Tensile Strength of Finished Fabrics at Different Treatments

The data on wrinkle recovery and tensile strength have been given in Table 9 and represented in Figure 8. From

TABLE 8

RELATIONSHIP BETWEEN TENSILE STRENGTH (lbs)
AND PERCENT FORMALDEHYDE OF FINISHED FABRICS
AT DIFFERENT TREATMENTS.

Treatment	Tensile Strength (lbs)	Formaldehyde (%)
T ₀	34.5	0
T _{MF}	26.1	1.6
T _{1MF}	26.0	2.0
T _{2MF}	25.0	2.1
T _{3MF}	24.8	2.4

T₀ - Untreated

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF - Melamine formaldehyde)

FIG. 7. RELATIONSHIP BETWEEN TENSILE STRENGTH (lbs) AND PERCENT FORMALDEHYDE OF FINISHED FABRICS AT DIFFERENT TREATMENTS.

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF = Melamine formaldehyde)

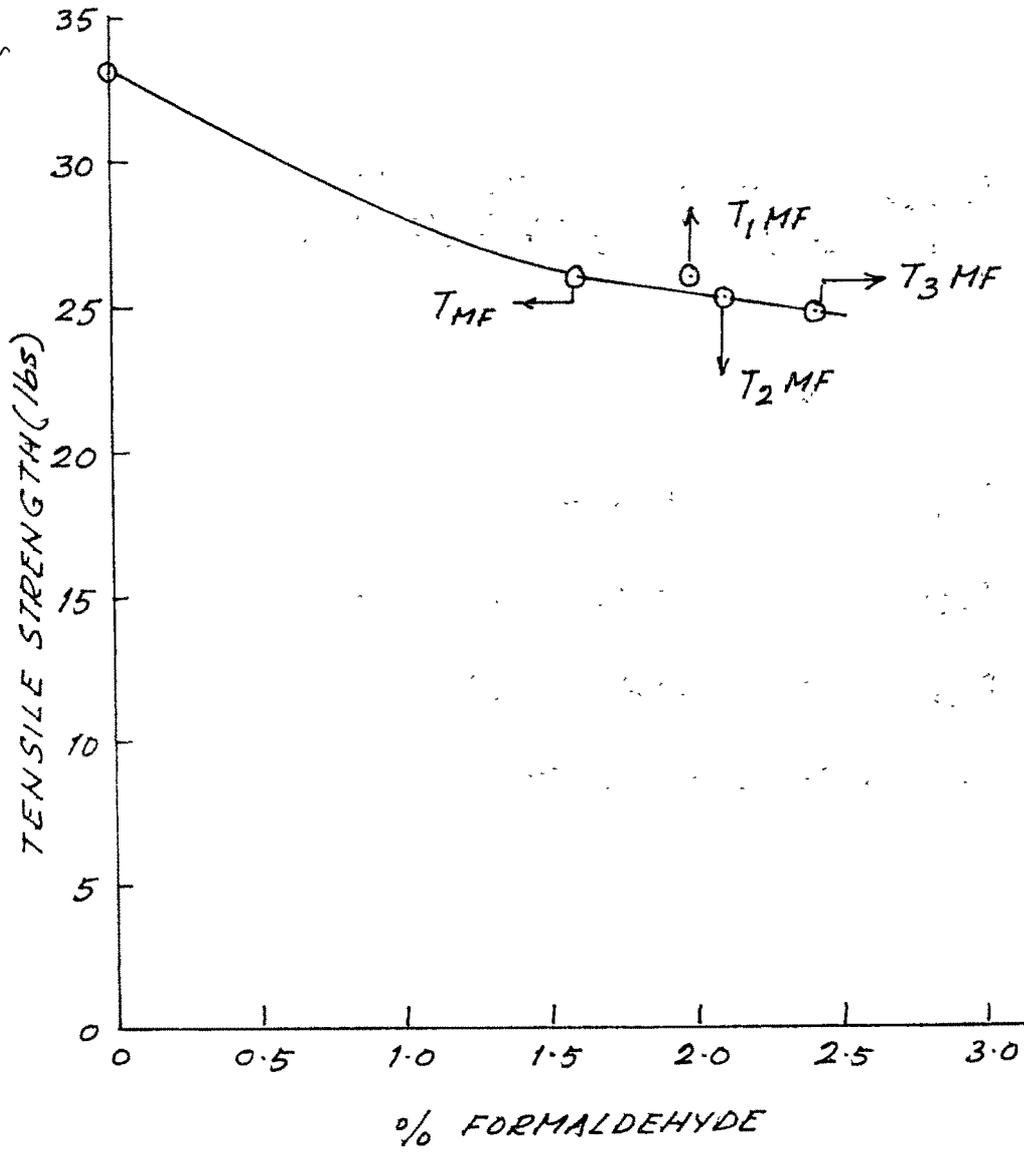


FIG. 7

RELATIONSHIP BETWEEN TENSILE STRENGTH (lbs) AND
PERCENT FORMALDEHYDE OF FINISHED FABRICS AT
DIFFERENT TREATMENTS

TABLE 9

RELATIONSHIP BETWEEN TENSILE STRENGTH (lbs)
AND WRINKLE RECOVERY (°) OF FINISHED FABRICS
AT DIFFERENT TREATMENTS.

Treatment	Wrinkle Recovery (°)	Tensile Strength (lbs)
T ₀	182	34.5
T _{MF}	231	26.1
T _{1MF}	255	26.0
T _{2MF}	252	25.0
T _{3MF}	275	24.8

T₀ - Unfinished

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF - Melamine formaldehyde)

FIG. 8. RELATIONSHIP BETWEEN TENSILE STRENGTH (lbs) AND WRINKLE RECOVERY (°) OF FINISHED FABRICS AT DIFFERENT TREATMENTS.

T_0 - Unfinished

T_{MF} - MF

T_{1MF} - MF + Diethylene glycol

T_{2MF} - MF + Polyethylene glycol - 200

T_{3MF} - MF + Polyethylene glycol - 400

(MF = Melamine formaldehyde)

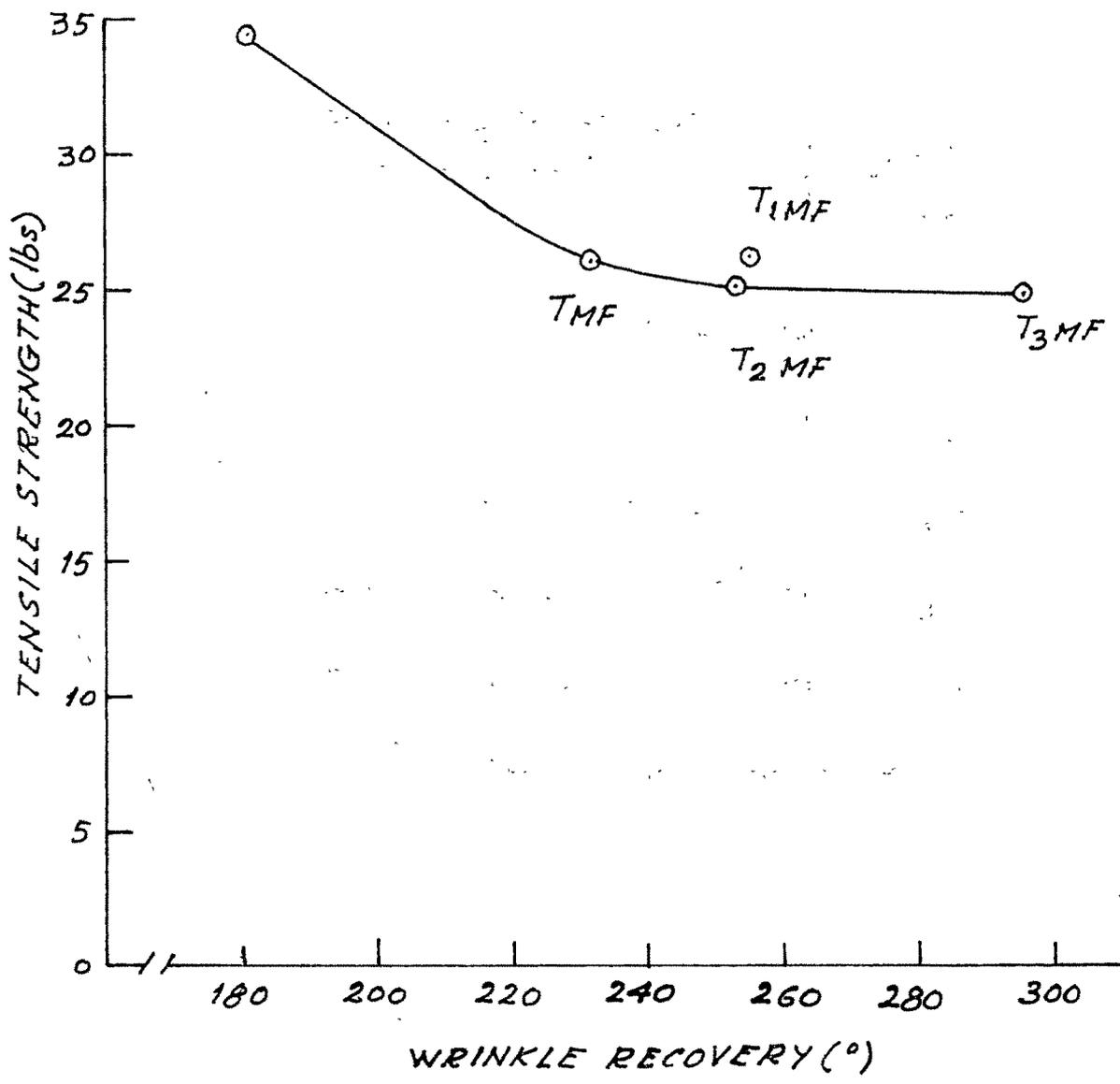


FIG. 8

RELATIONSHIP BETWEEN WRINKLE RECOVERY (°) AND TENSILE STRENGTH (lbs) OF FINISHED FABRICS AT DIFFERENT TREATMENTS

the figure it is observed that the improvement in wrinkle recovery and loss of strength go together upto certain limits, studied in this work. While from the latter part of the curve it was indicated that polyhydroxy compounds along with melamine formaldehyde have not caused further loss in strength. The observed lower strength losses were attributed to the chemical reactivity of polyhydroxy compounds. No specific generalisation were possible since the observed points were closer.

Theoretical Consideration of Reactions and Linkages

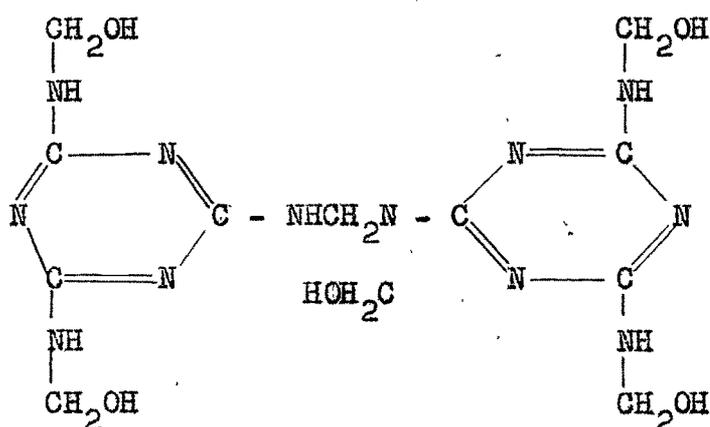
In the present study an attempt has been made to explain the possible reactions and linkages of different treatments on the basis of changes in the physical properties and formaldehyde analysis.

1. The formation of three dimensional polymeric net work with melamine formaldehyde as given in reaction I(i,ii), page 61.
2. The formation of short oxy-methylene ($O-CH_2-$) linkages between cellulose chains as given in reaction II, page 62.
3. The formation of amido methyl ether between unreacted methylol groups of resin and end hydroxyl groups of polyethylene glycols as given in reaction III, page 62. Such a reaction has been suggested by Andrews et al. (7).
4. The formation of linear polymeric acetal resin with polyhydroxy compounds, and formaldehyde as given in reaction IV(i,ii), page 63.

REACTIONS AND LINKAGES

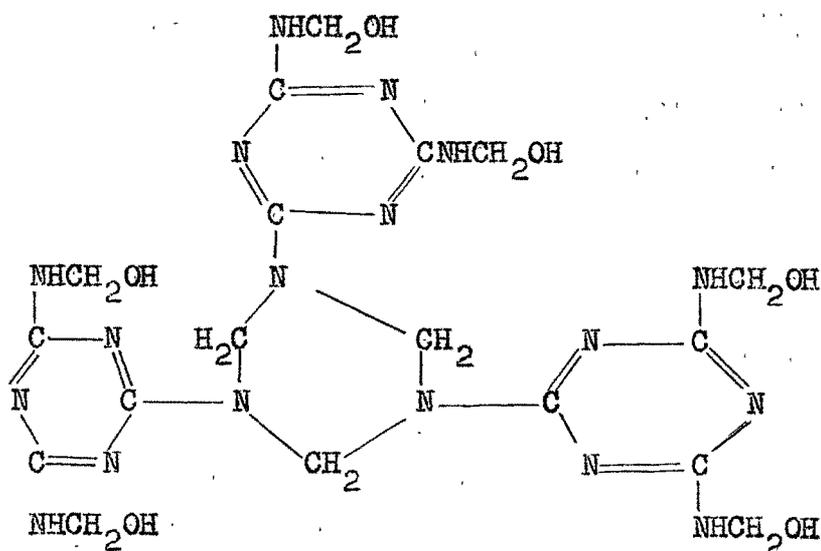
Reaction I

Polymeric net work of melamine formaldehyde (19)



Linear Condensation

(i)

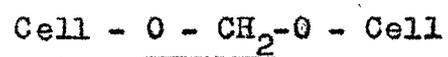
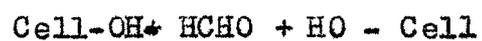
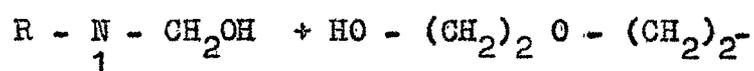


Cyclic Condensation

(ii)

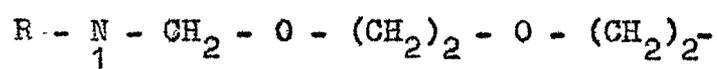
Reaction II

Cross-linkage of cellulose with formaldehyde

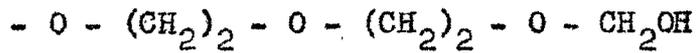
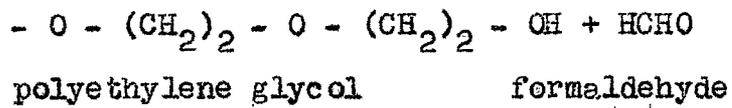
Reaction III

methylol group

polyethylene glycol



amidomethylether

Reaction IV

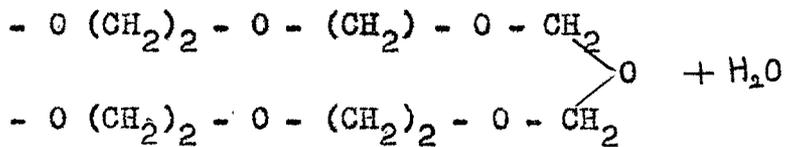
Hemiacetal

(i)

Two hemiacetal react further by loss of water



+



polymeric acetal

(ii)

It is however stated that no specific type of linkages mentioned above be emphasized. A co-ordination complex formation of different linkages as suggested by Marsh (19) can be attributed to the changes in the properties of finished cotton fabric.