CHAPTER IV

RESULT AND DISCUSSION

4.1 Parameters Affecting Mixing and Quality of EVA Compounds

All the experimental datas were shown in Figure 4.1-4.15 and Table 4.1. The results were summerized in Table 4.2.

4.1.1 Effect of Compounding Stage 1 on Shear Viscosity

Figure 4.1 showed the effect of stage 1 compounding time on shear viscosity. The shear viscosity began to be constant at 20 minutes and there was a little decrease after 30 minutes. Therefore, the time required for uniform distribution was selected to be between 25-30 minutes.

Table 4.1 Effect of stage 1 compounding time on shear viscosity

Formulation No.	Shear Viscosity (kPaS)						Shear Rate (1/s)
	Compounding stage 1 (min)						
	10	15	20	25	30	35	
No.1-No.7	4.04	3.61	3.39	3.23	3.23	3.18	20
	3.37	2.95	2.82	2.73	2.73	2.69	50
	2.49	2.21	2.08	1.99	1.99	1.95	100
	1.08	0.95	0.92	0.89	0.89	0.08	200

Note. Without DCP,AK#2 and ZnO

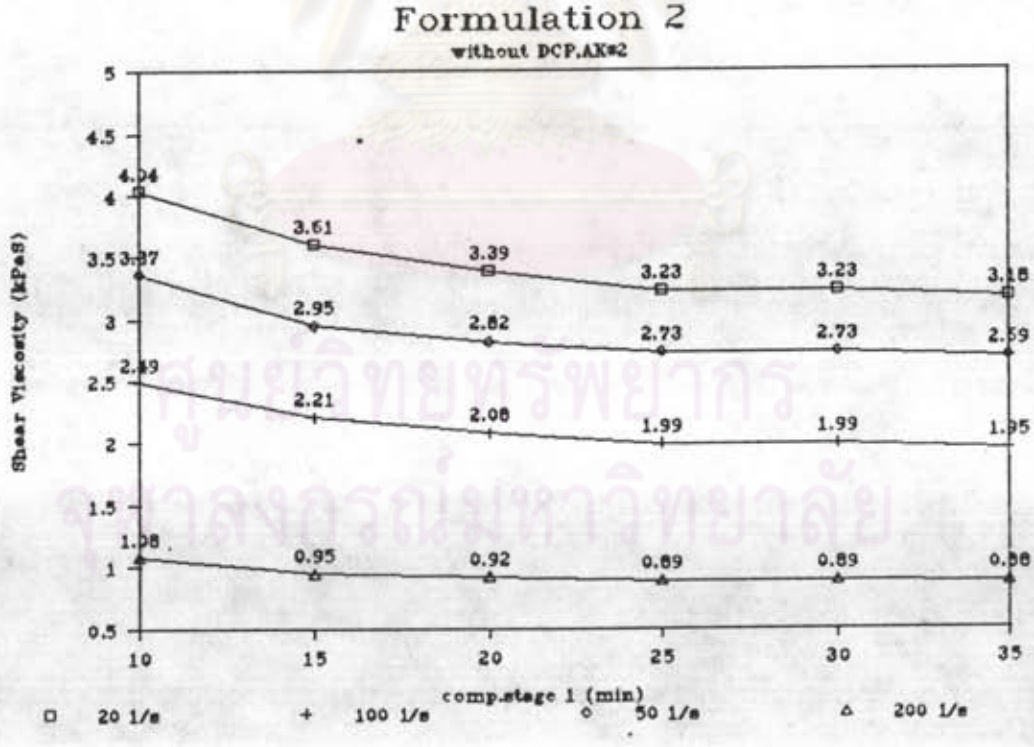


Figure 4.1 Effect of stage 1 compounding time on shear viscosity.

4.1.2 Effect of Process Parameters on Foaming

Figure 4.2 showed the effect of stage 2 compounding time on the foaming. The longer stage 2 compounding time decreased the foaming. On the other hand, the stage 3 compounding time had no effect on the foaming (as shown in Figure 4.3). It was expected that the temperature in stage 2 (105^{o}C) also had some effect on the decomposition of the blowing agent.

Figure 4.4, the level of zinc oxide had a negligible effect on the foaming. However, the foaming was increased when the level of the blowing agent was increased (as shown in Figure 4.5). The foaming of different level of the blowing agent began to be small increasing at above 13 minutes and the time was selected to study.

Figure 4.6, 4.7 and 4.8, the storage time was shown to be a very important parameter affecting the foaming, but the level of zinc oxide had no effect . The foaming was increased when the storage time was increased. The effect of storage time can be explained by the possible formation of a intermediate which can decompose more easily and efficiently.

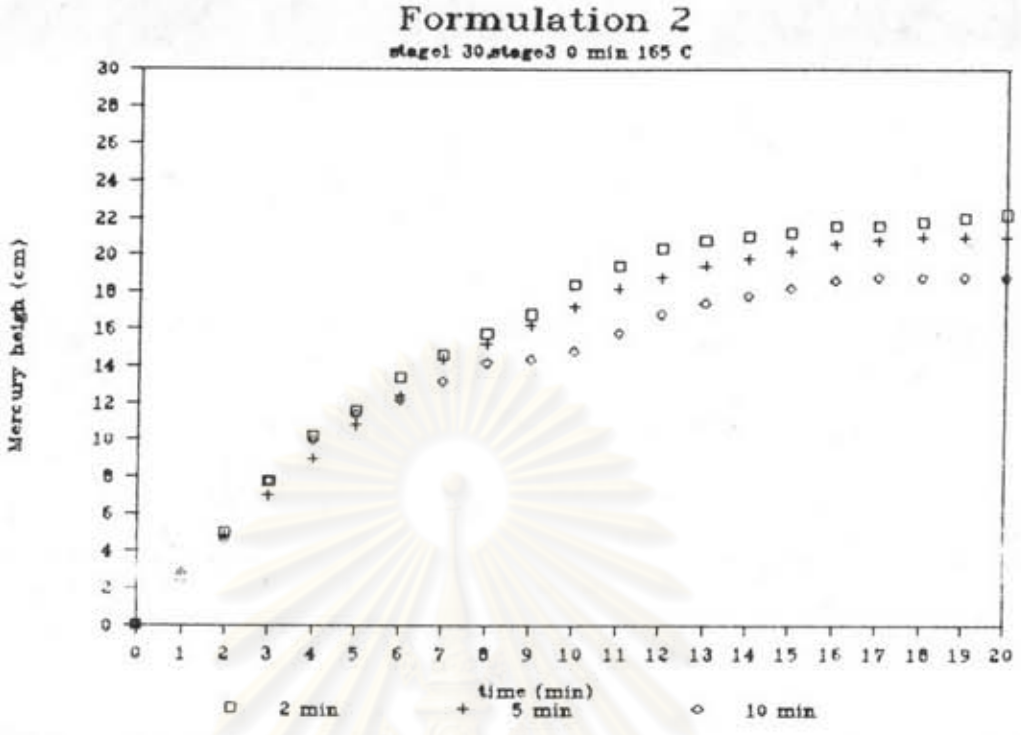


Figure 4.2 Effect of stage 2 compounding time on foaming (storage 2 hr.).

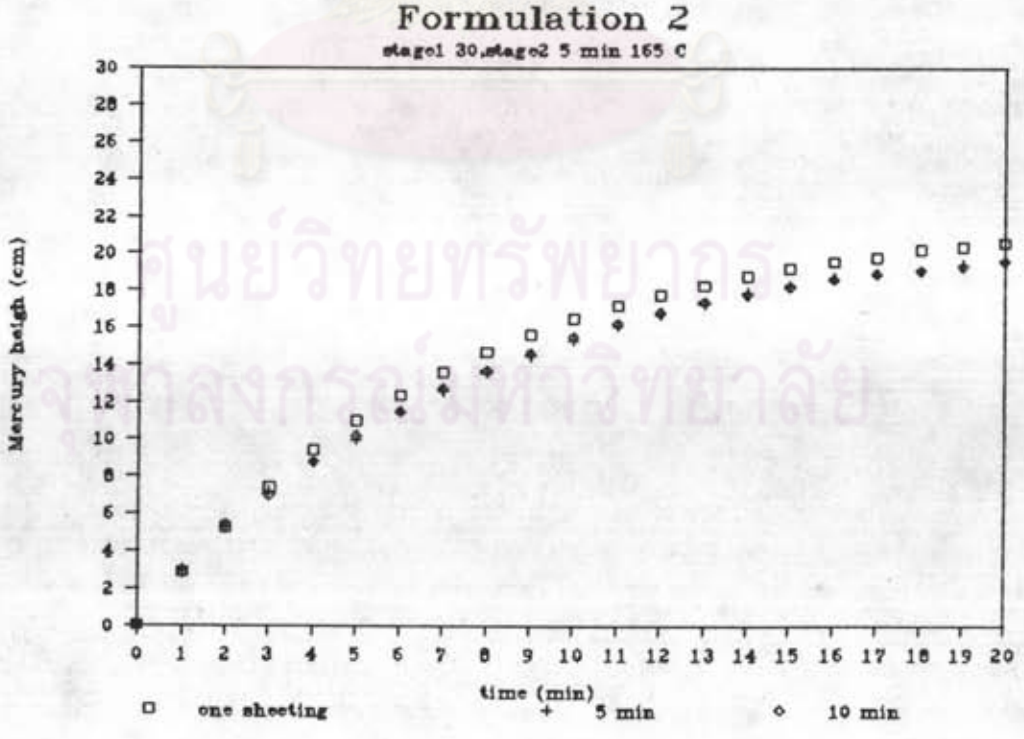


Figure 4.3 Effect of stage 3 compounding time on foaming (storage 2 hr.).

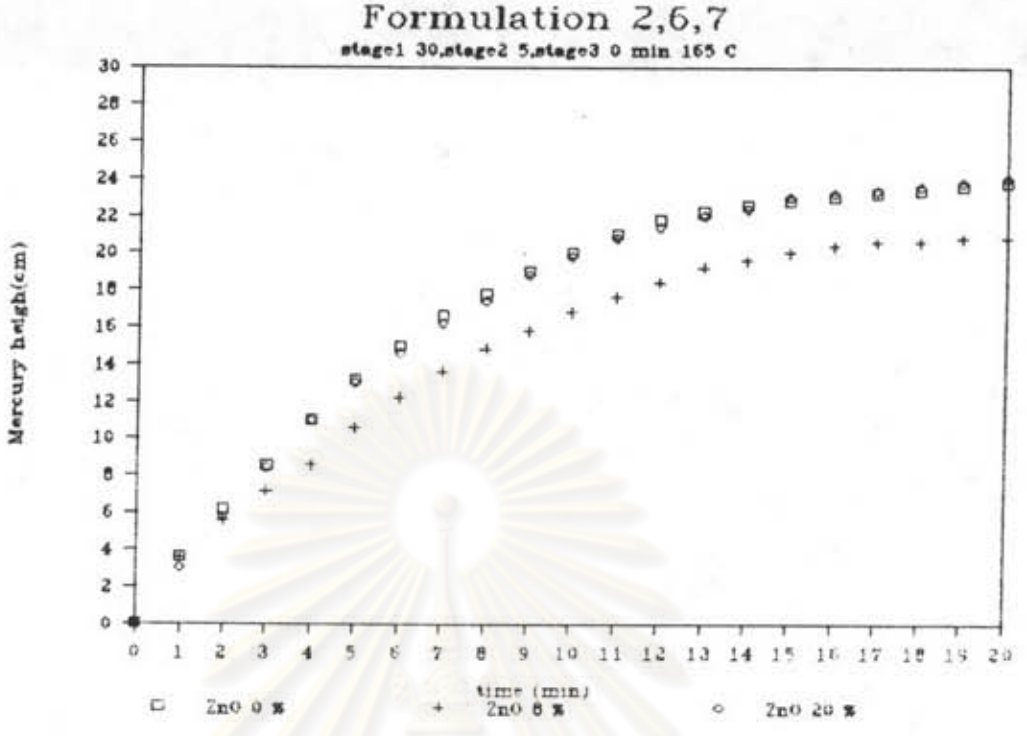


Figure 4.4 Effect of level of zinc oxide on foaming (storage 2:20 hr.).

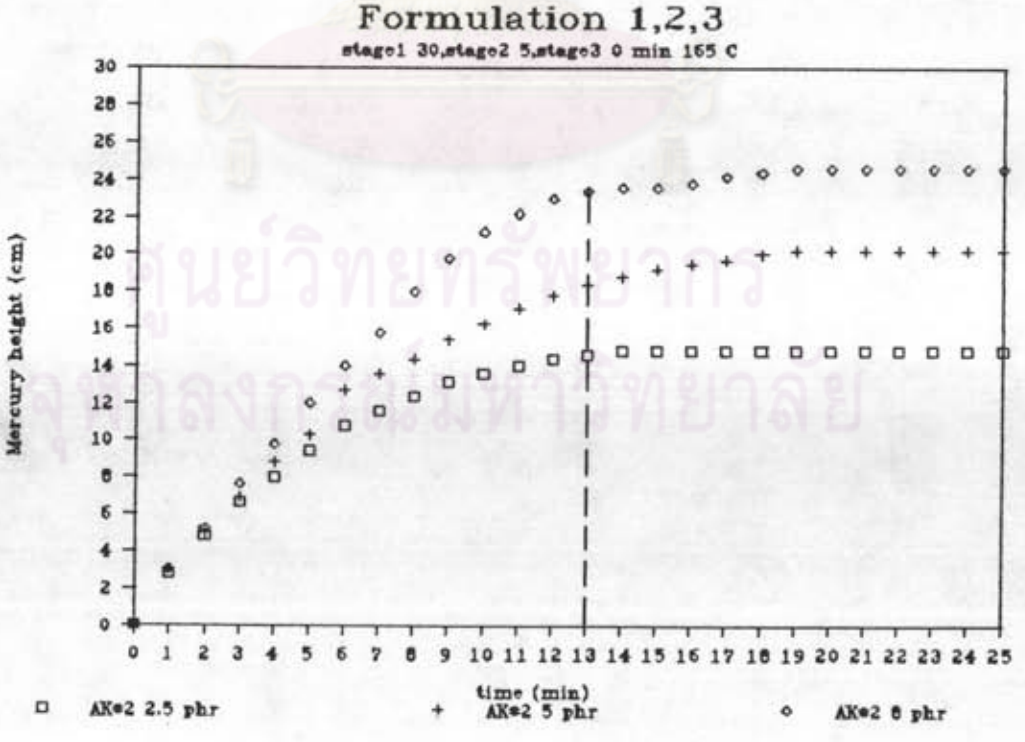


Figure 4.5 Effect of level of blowing agent on foaming (storage 1:25 hr.).

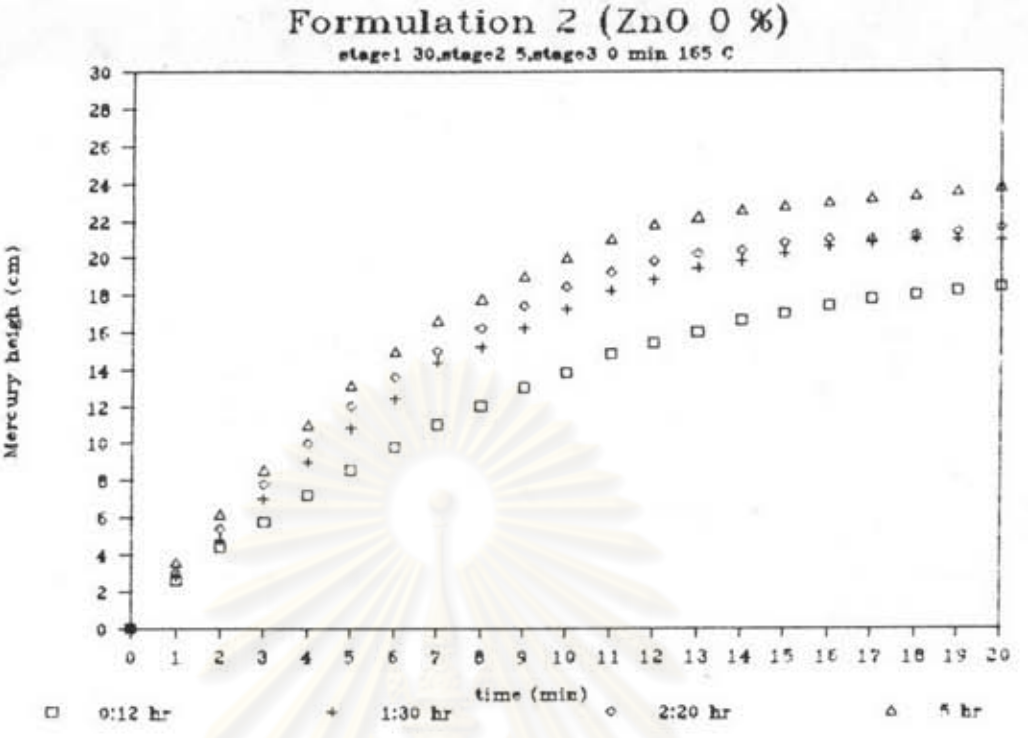


Figure 4.6 Effect of storage time on foaming (zinc oxide 0%).

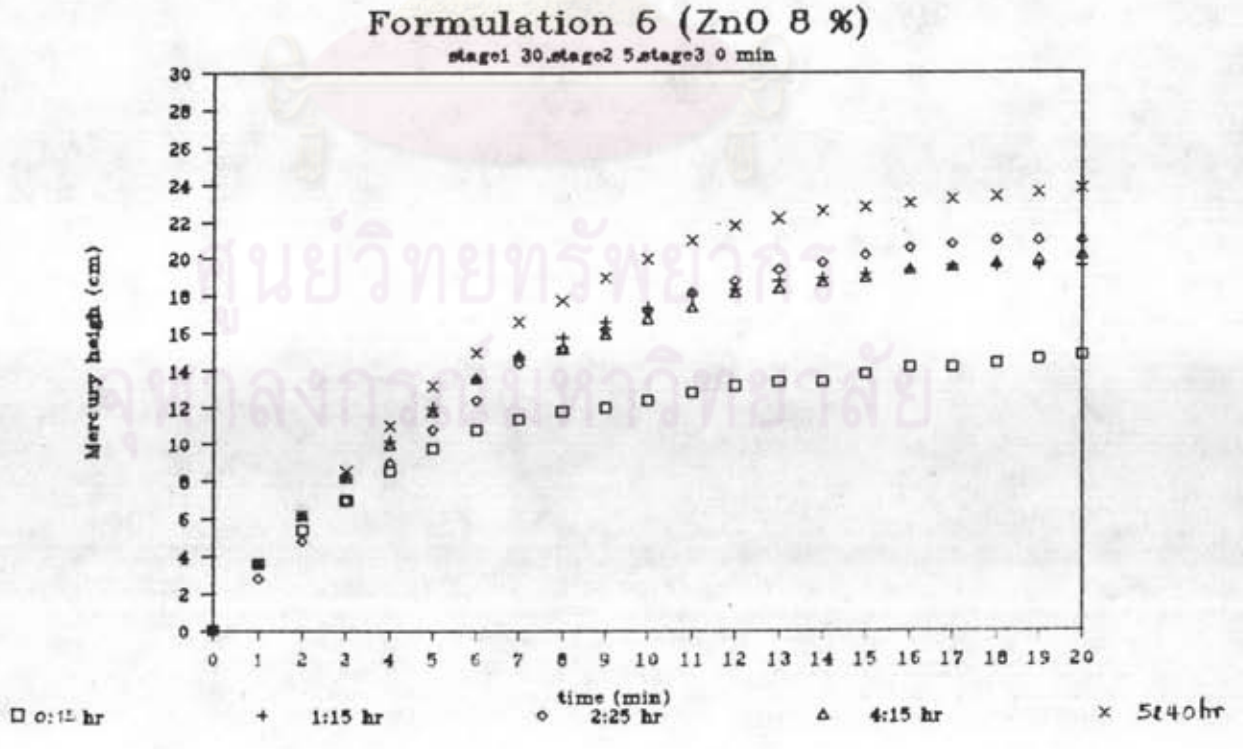


Figure 4.7 Effect of storage time on foaming (zinc oxide 8%).

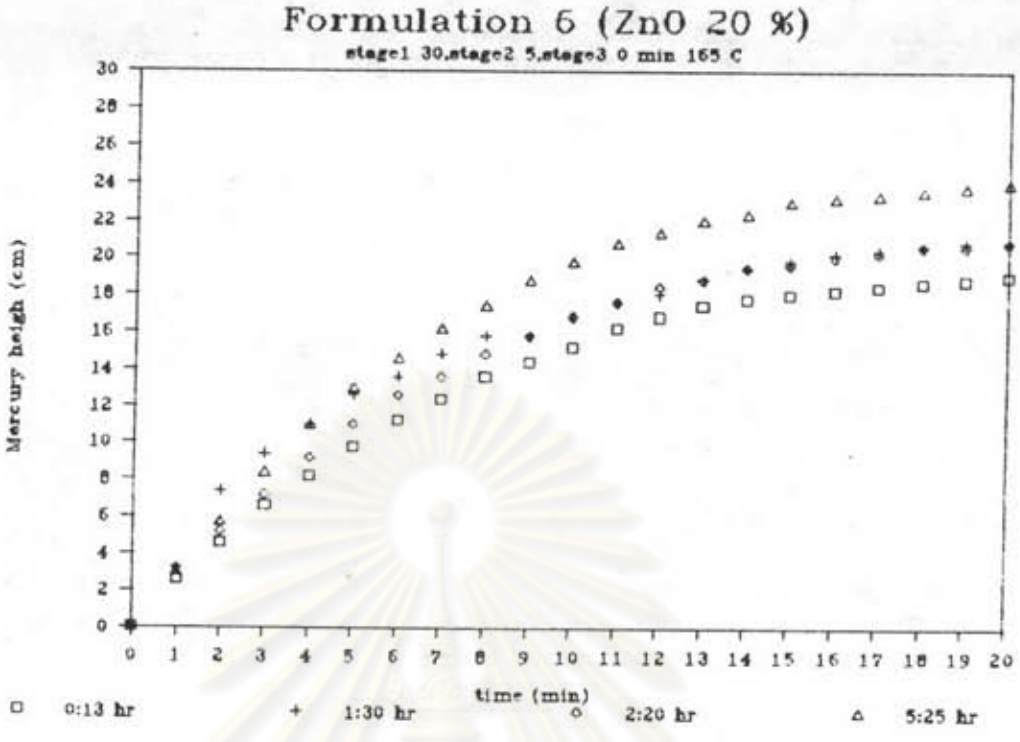


Figure 4.8 Effect of storage time on foaming (zinc oxide 20%).

4.1.3 Effect of Process Parameters on Cross-linking

From Figure 4.9 and 4.10, the stage 2 and stage 3 compounding time had no effect on the cross-linking. The level of zinc oxide seemed to have some effect of increasing the cross-linking at temperature 165°C but have negligible effect at temperature 185°C (as shown in Figure 4.11). Therefore, zinc oxide seemed to have lillte effect on the cross-linking. Figure 4.12 emphasized the effect of cure temperature on increasing the cross-linking. The 90 percent cross-linking time was 13 minutes at cure temperature 165°C, and 4 minutes at cure temperature 185°C. The cure times were selected to study.

The level of cross-linking agent increased the cross-linking according to Figure 4.13. Figure 4.14 and 4.15 showed that the storage time had no effect on the cross-linking and the amount of zinc oxide also did not affect the cross-linking even with a longer storage time. From these results showed that the compound was not scorched between compounding stages and storage.

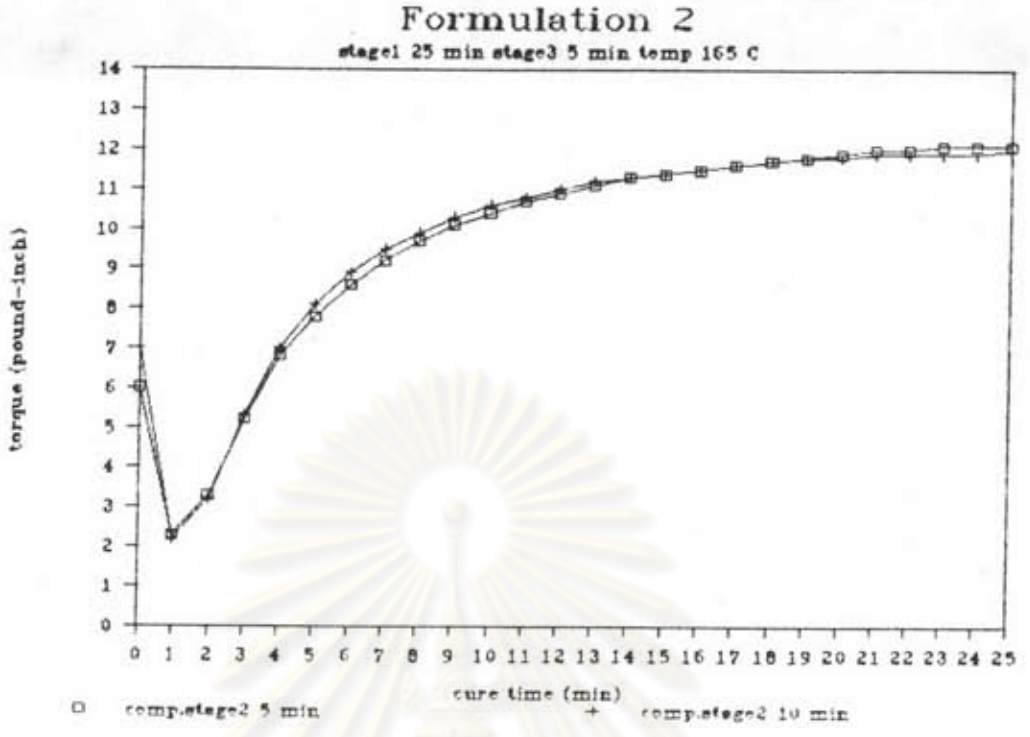


Figure 4.9 Effect of stage 2 compounding time on cross-linking.

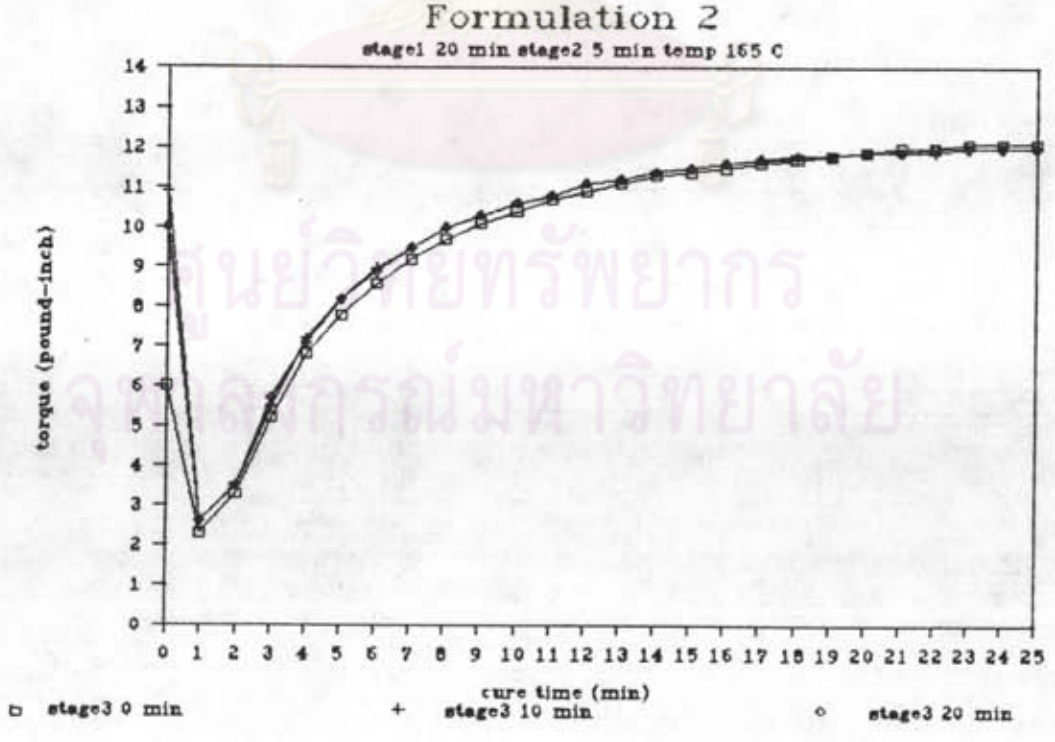


Figure 4.10 Effect of stage 3 compounding time on cross-linking.

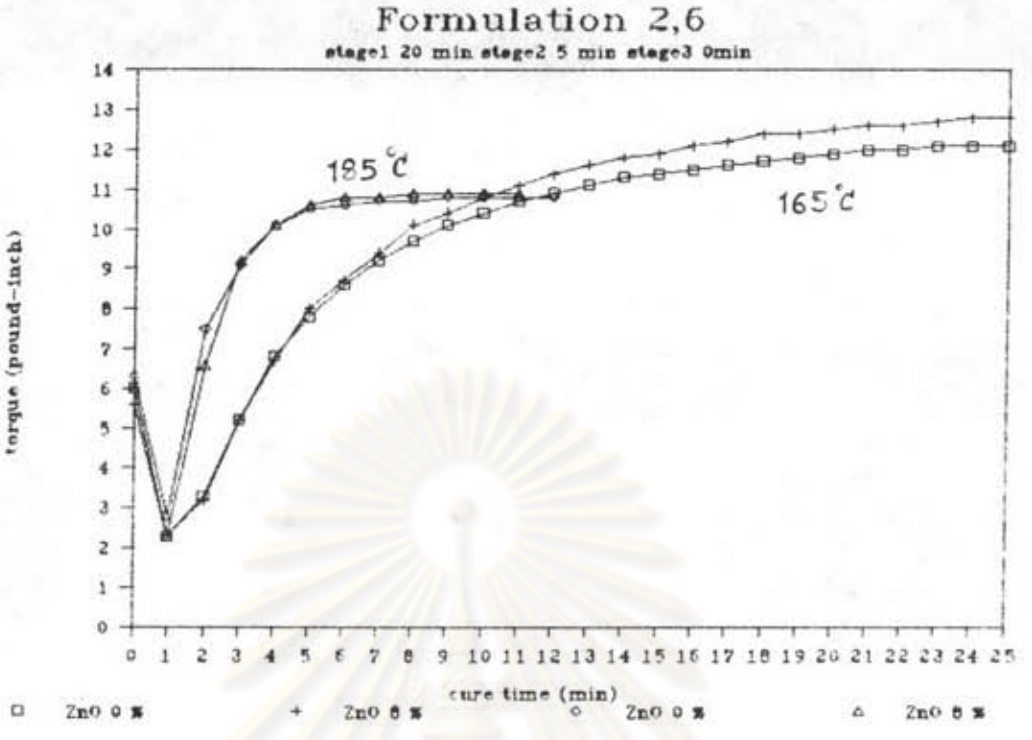


Figure 4.11 Effect of level of zinc oxide and cure temperature on cross-linking.

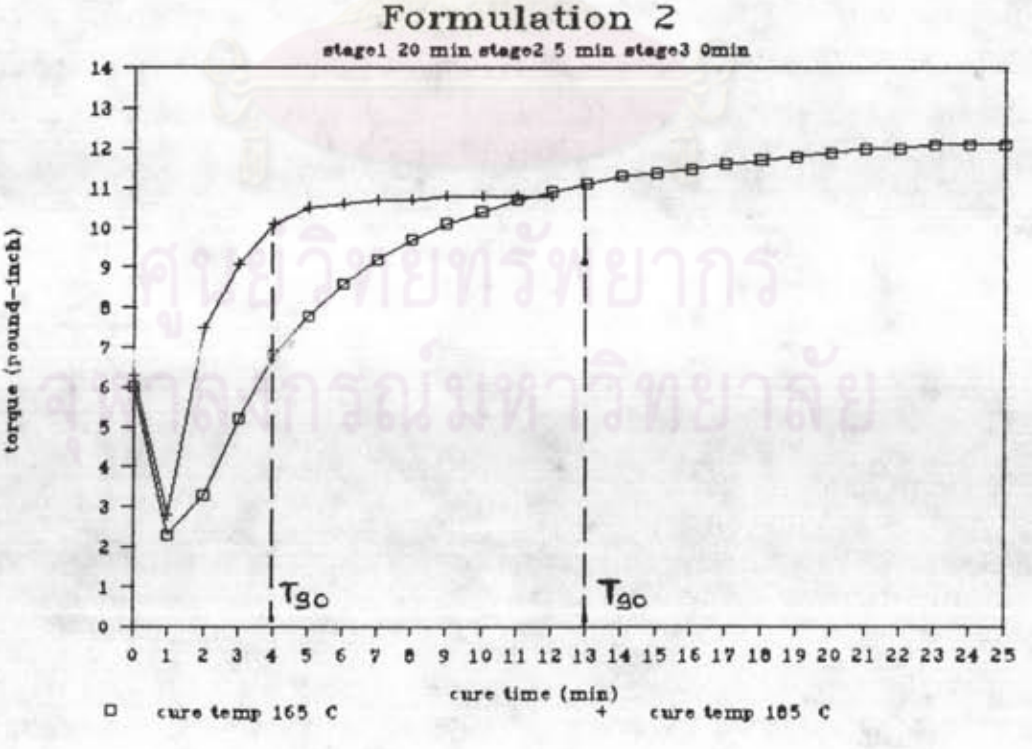


Figure 4.12 Effect of cure temperature on cross-linking.

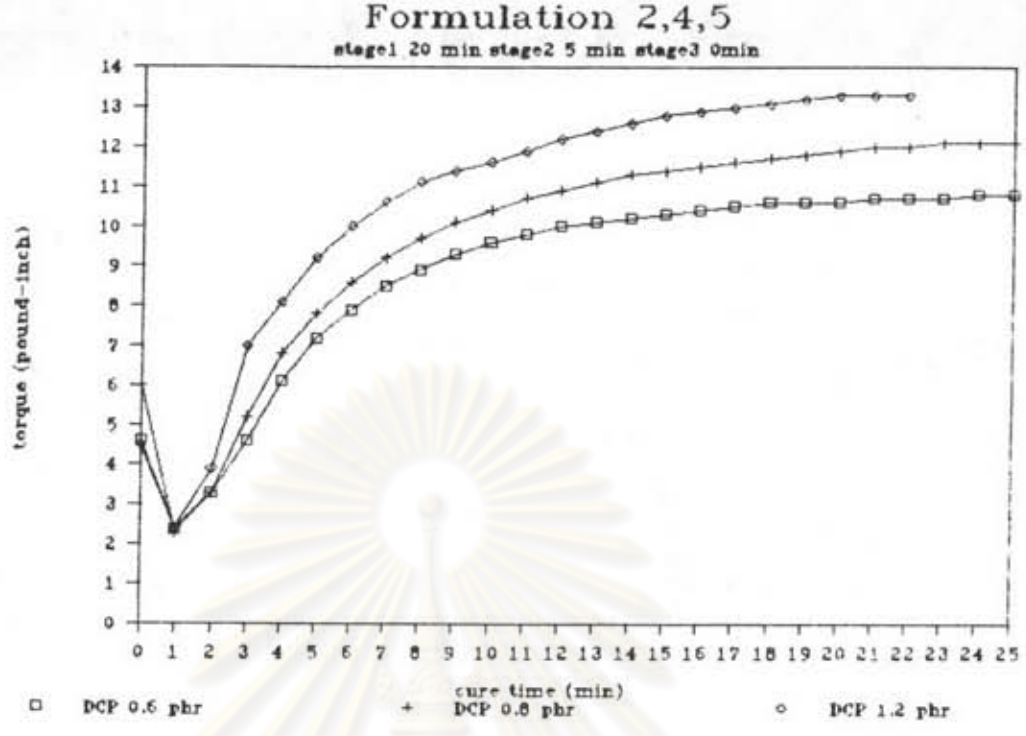


Figure 4.13 Effect of level of cross-linking agent on cross-linking.

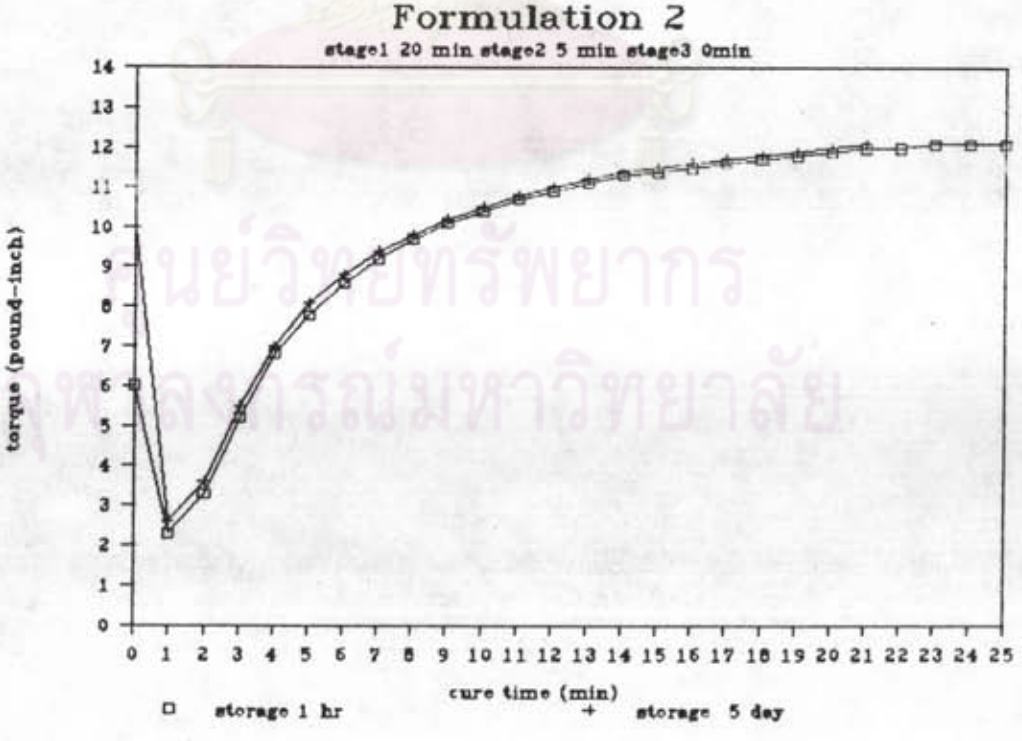


Figure 4.14 Effect of storage time on cross-linking (zinc oxide 0%).

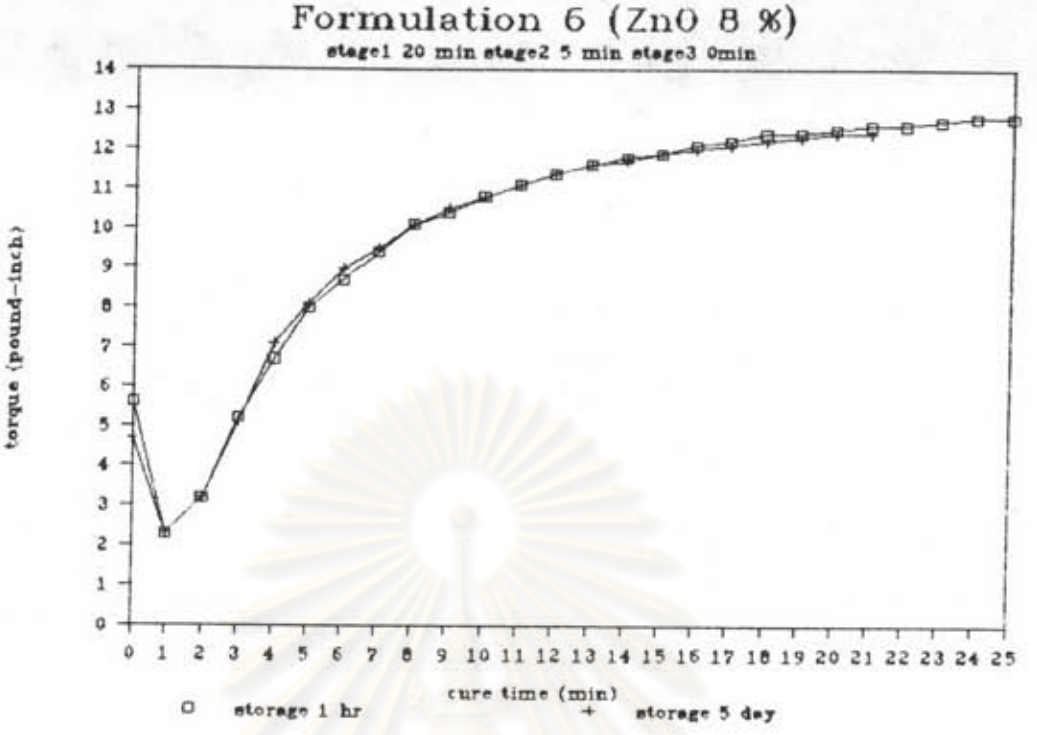


Figure 4.15 Effect of storage time on cross-linking (zinc oxide 8%).

4.1.4 Summerize the Effect of Process Parameters on Cross-Linking/Foaming

From the above results of various trials (Formulation No.1 - No.7), the effects of various parameters could be summarized in Table 4.2.

The cross-linking was affected by the level of the cross-linking agent and the cure temperature. At temperature 165^{o}C,zinc oxide had little effect on the cross-linking. The compounding time of various stages and storage time had no effect on the cross-linking.

The foaming depended on the level of the blowing agent and the cure temperature. The longer stage 2 compounding time decreased the foaming. The optimum storage time was required to increase the foaming.

Table 4.2 Summerize the effect of process parameters on cross-linking/foaming

Parameter		Foaming	Cross-linking
Compounding			
-stage 1			
-stage 2	increase	decrease	unchange
-stage 3	increase	unchange	unchange
storage time	increase	increase	unchange
Temperature	increase		increase
Formulation			
-Blowing agent	increase	increase	
-Cross-linking agent	increase		increase
-Zinc oxide	increase	unchange	increase(165°C.) unchange(185°C.)

4.2 Effect of Process Parameters on Various Physical Properties

4.2.1 Effect of Stage 1 Compounding Time on Physical Properties

The time interval of compounding stage 1 between 25-30 minutes had no effect on various physical properties of the foam under the same cure condition. (Table 4.3 and Figure 4.16-4.22).These effects could be explained that the compound was uniform distribution during this interval.Except the compression set of the foam (stage 1 compounding time 25 minutes) was rather constant where as the compression set of the foam (stage 1 compounding time 30 minutes) was decreased with increasing cure time. Because the cells of the foam (stage 1 compounding time 30 mintues) tended to be spherical, but the cells of the foam (stage 1 compounding time 25 minutes) were squeeze (Appendix E). So, the stage 1 compounding time 30 minutes was selected to study.

Table 4.3 Effect of stage 1 compounding time on physical properties

Physical Properties	Cure time (min.) / stage 1 (min.)	13	18	23	28
Density (g/cm^3)	25	0.19	0.16	0.14	
	30	0.19	0.15	0.13	0.13
Hardness (Type C)	25	53	46	43	
	30	53	47	41	40
Expansion ratio (Volumetric)	25	4.2	5	5.6	
	30	4.3	5.2	5.9	6.2
Tensile strength (N/cm^2)	25	200	164	145	
	30	194	163	147	138
Tear strength (N/mm)	25	10.6	8.6	7	
	30	10.2	8.5	7.2	6.8
Elongation (%)	25	150	120	110	
	30	150	120	117	115
Compression set (%)	25	3.9	3.9	3.3	
	30	5.3	4	1.9	1.4

Formulation 2: Compounding stage 2 5 min.
Compounding stage 3 10 min.
Storage time 1 hr.
Cure temperature 165°C.

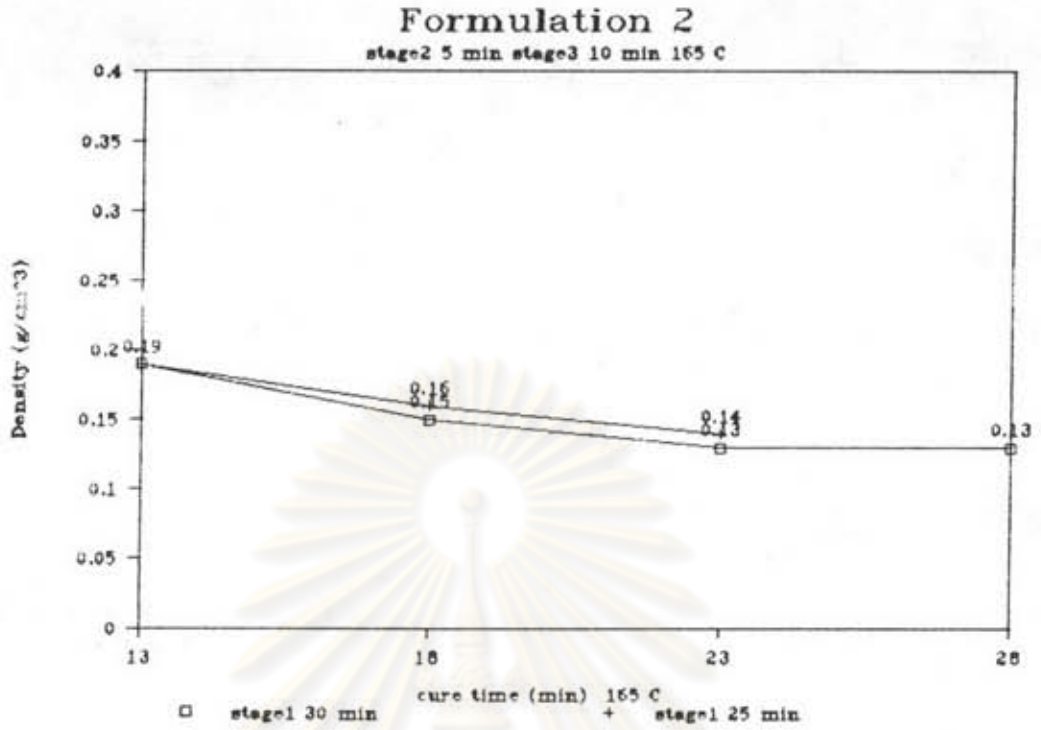


Figure 4.16 Effect of stage 1 compounding time on density.

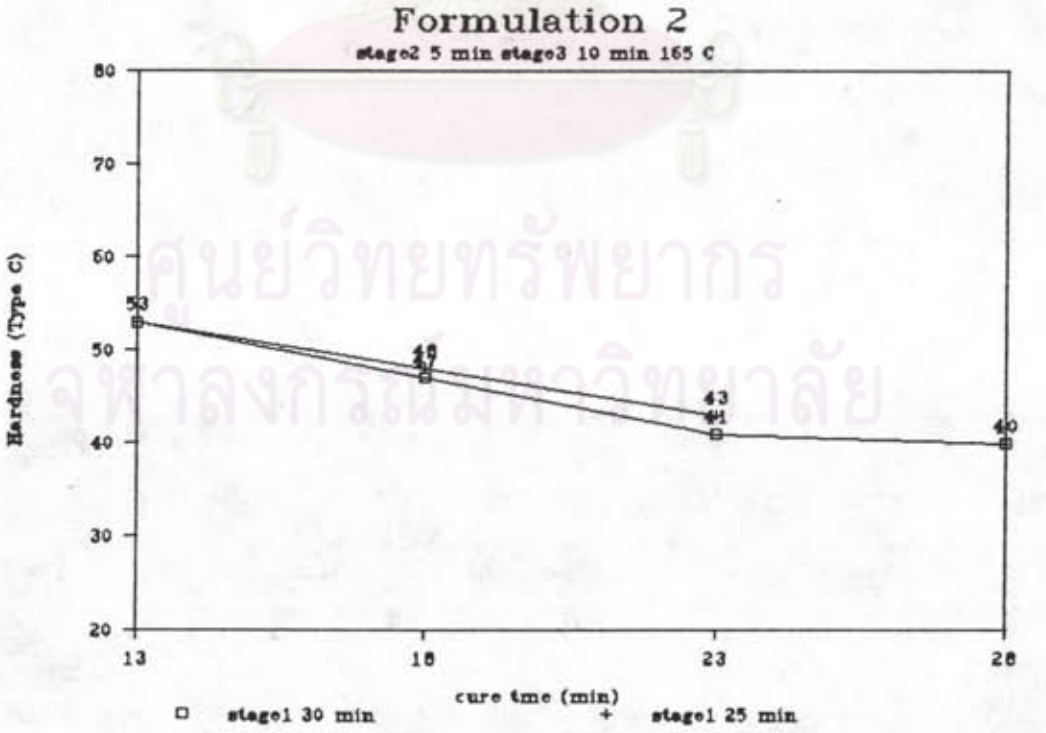


Figure 4.17 Effect of stage 1 compounding time on hardness.

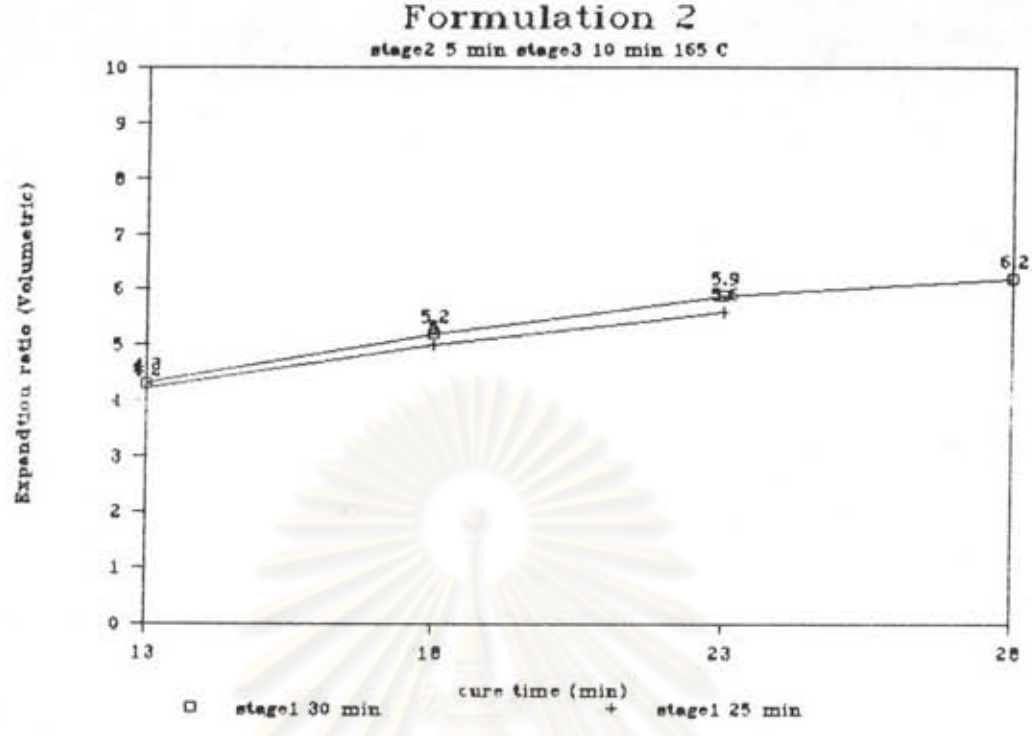


Figure 4.18 Effect of stage 1 compounding time on expansion ratio.

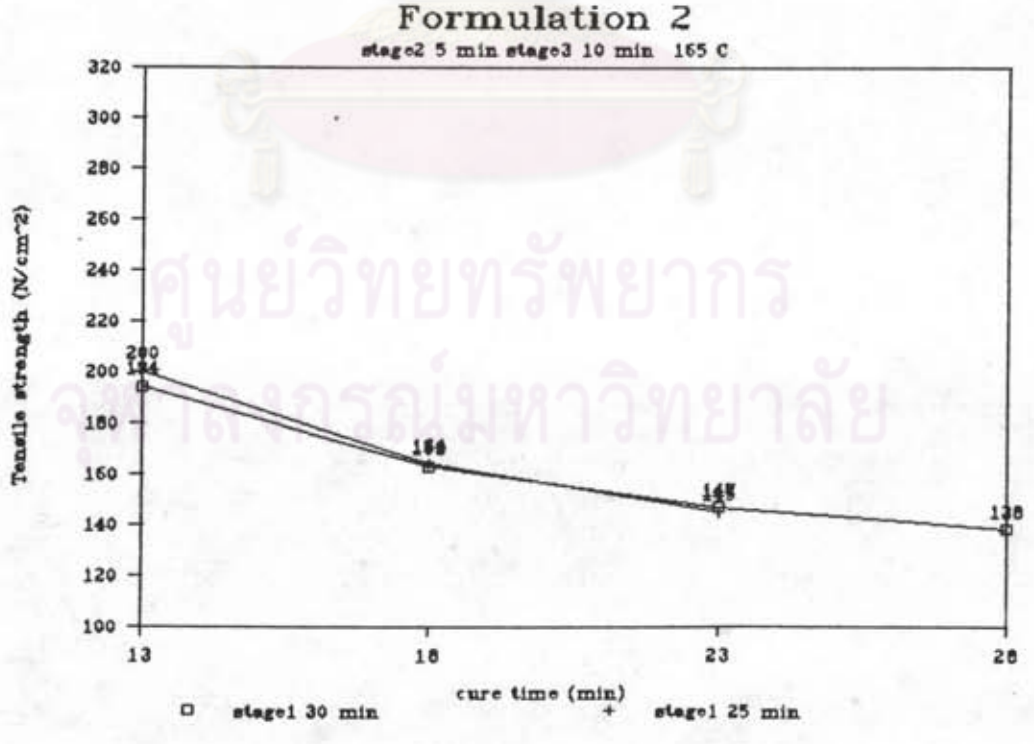


Figure 4.19 Effect of stage 1 compounding time on tensile strength.

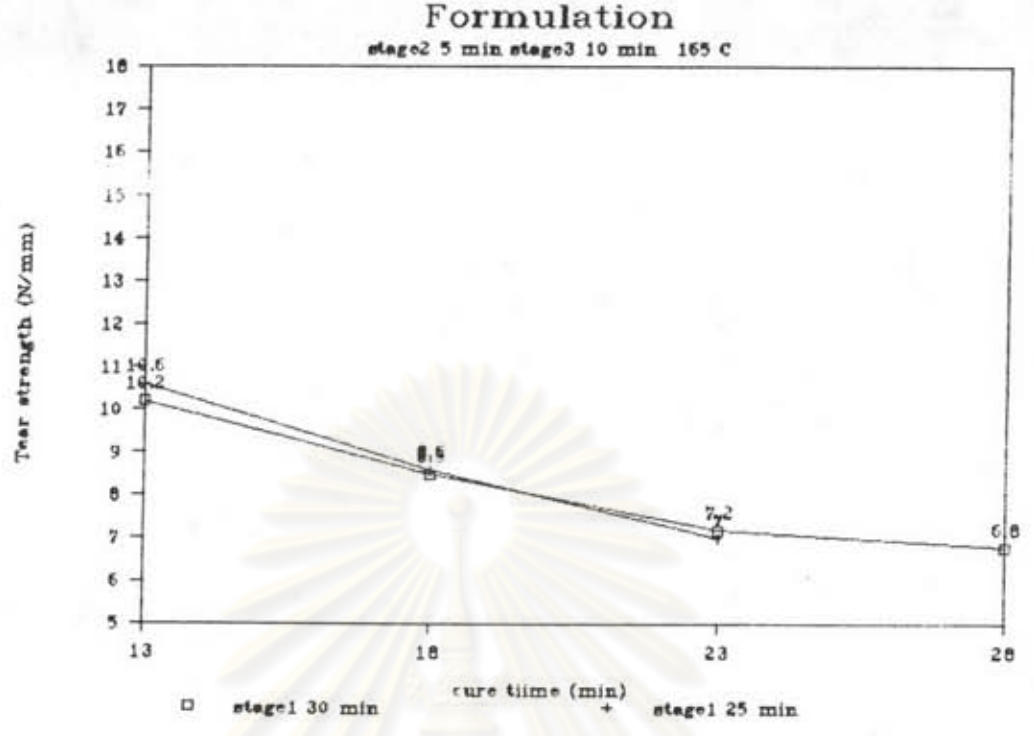


Figure 4.20 Effect of stage 1 compounding time on tear strength.

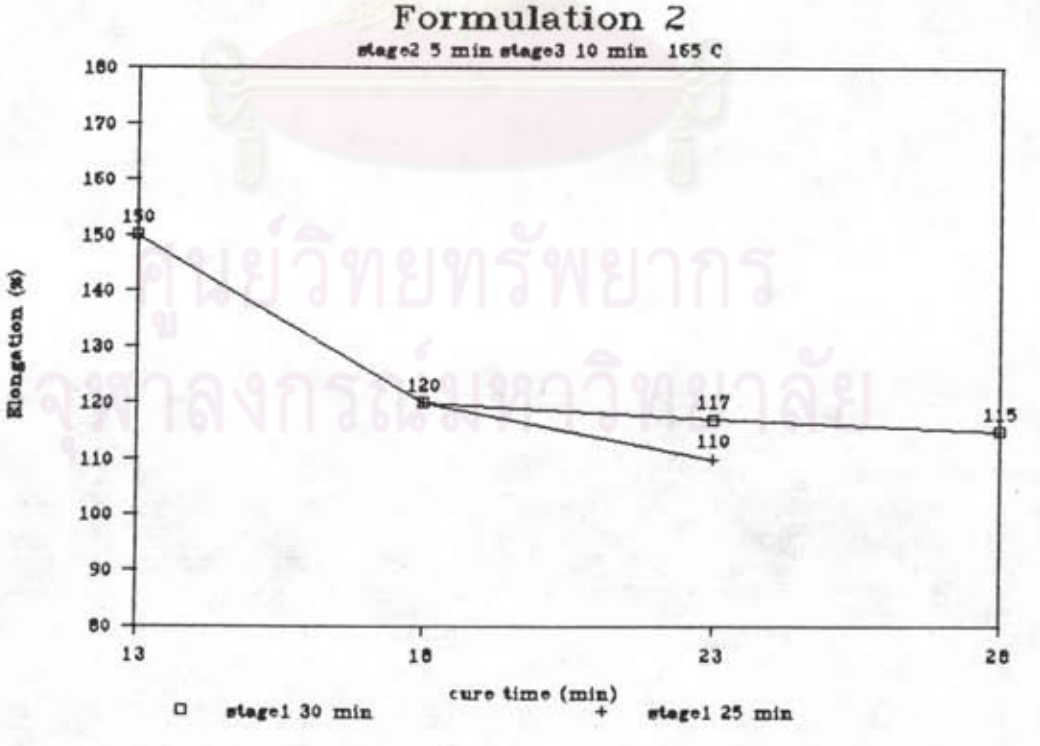


Figure 4.21 Effect of stage 1 compounding time on elongation.

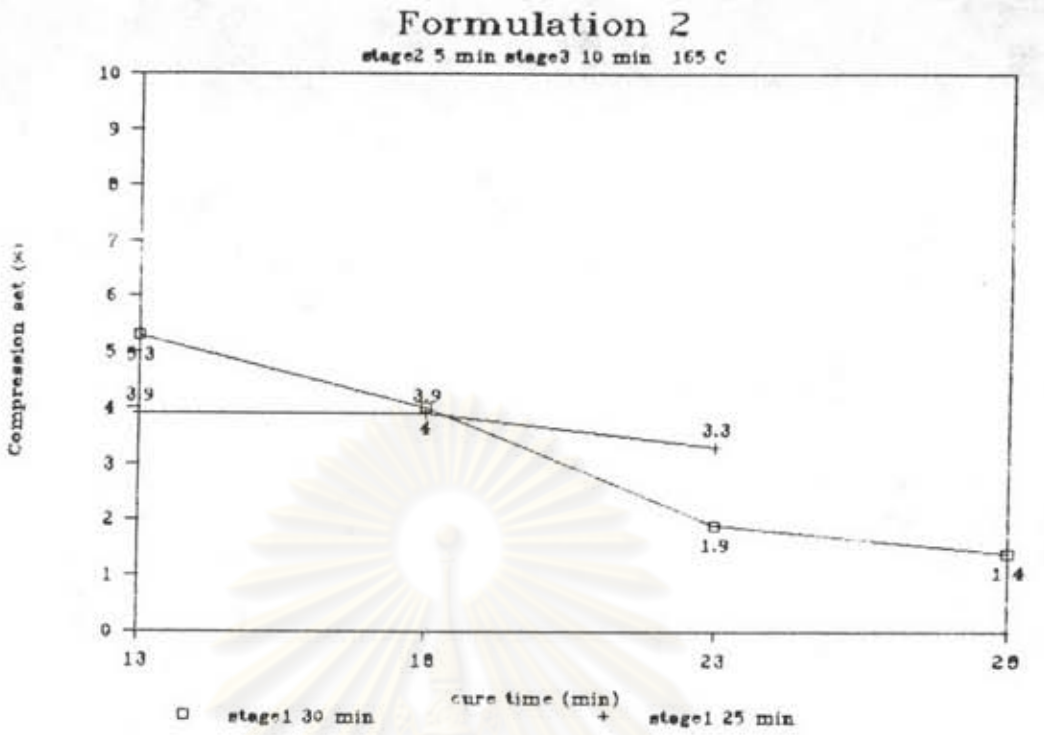


Figure 4.22 Effect of stage 1 compounding time on compression set.

4.2.2 Effect of Stage 2 Compounding Time on Physical properties

From Table 4.4 and Figure 4.23-4.29,the various physical properties, e.g. density, hardness, etc.,except the expansion ratio, of the foam increased with the increasing of the stage 2 compounding time. Such effects corresponded with the results from Figure 4.2 which showed the decreasing of the foaming during the longer time interval of stage 2 and the cross-linking was unchange as shown in Figure 4.9. From these results, the stage 2 compounding time about 5 minutes was optimum because the foaming was little decreased and it was practical in dispesrion of blowing agent.

Table 4.4 Effect of stage 2 compounding time on physical properties

Compounding stage 2 (min.) / Physical Properties	2	5	10	15
Density (g/cm^3)	0.14	0.16	0.18	0.18
Hardness (Type C)	43	50	53	53
Expansion ratio (Volumetric)	5.7	4.9	4.3	4.2
Tensile strength (N/cm^2)	136	179	189	183
Tear strength (N/mm.)	6.6	8.7	10.4	9.8
Elongation (%)	125	130	130	137
Compression set (%)	2.2	3.5	4.2	4.3

Formulation 2: Compounding stage 1 30 min.
Compounding stage 3 0 min.
Storage time 1 hr.
Cure 165°C. 18 min.

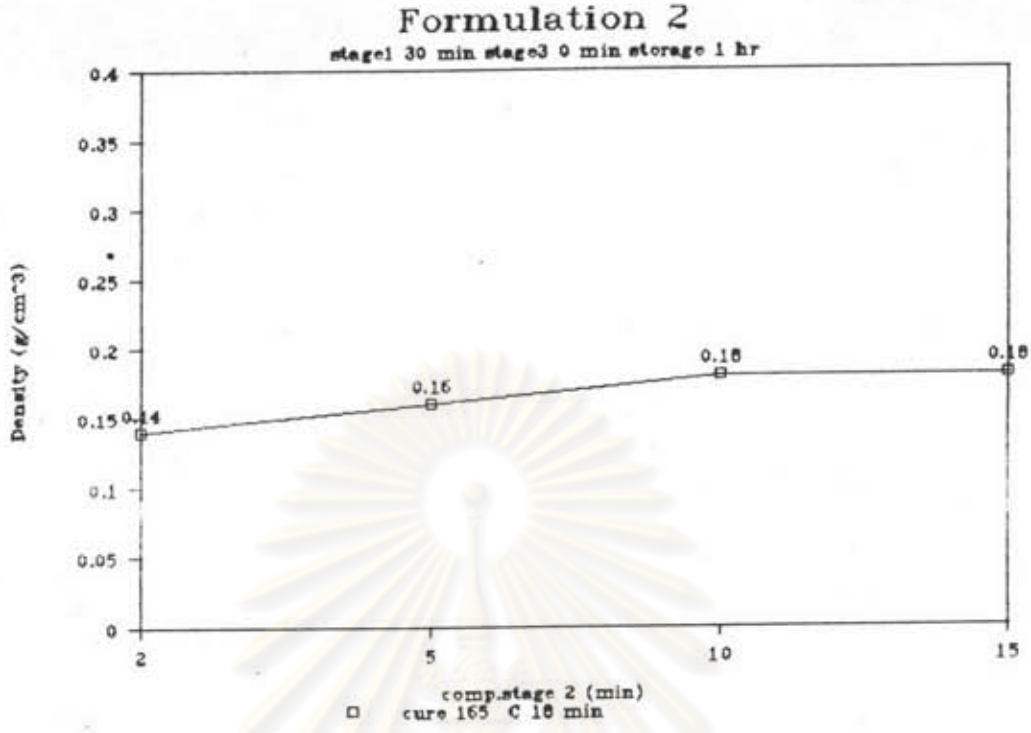


Figure 4.23 Effect of stage 2 compounding time on density.

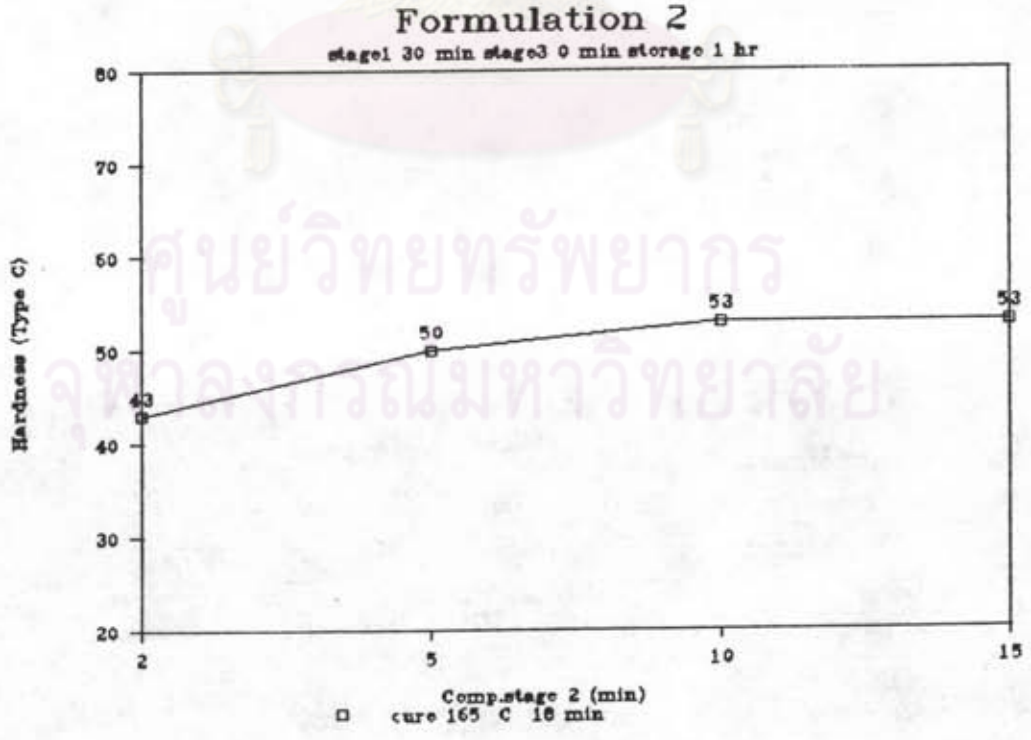


Figure 4.24 Effect of stage 2 compounding time on hardness.

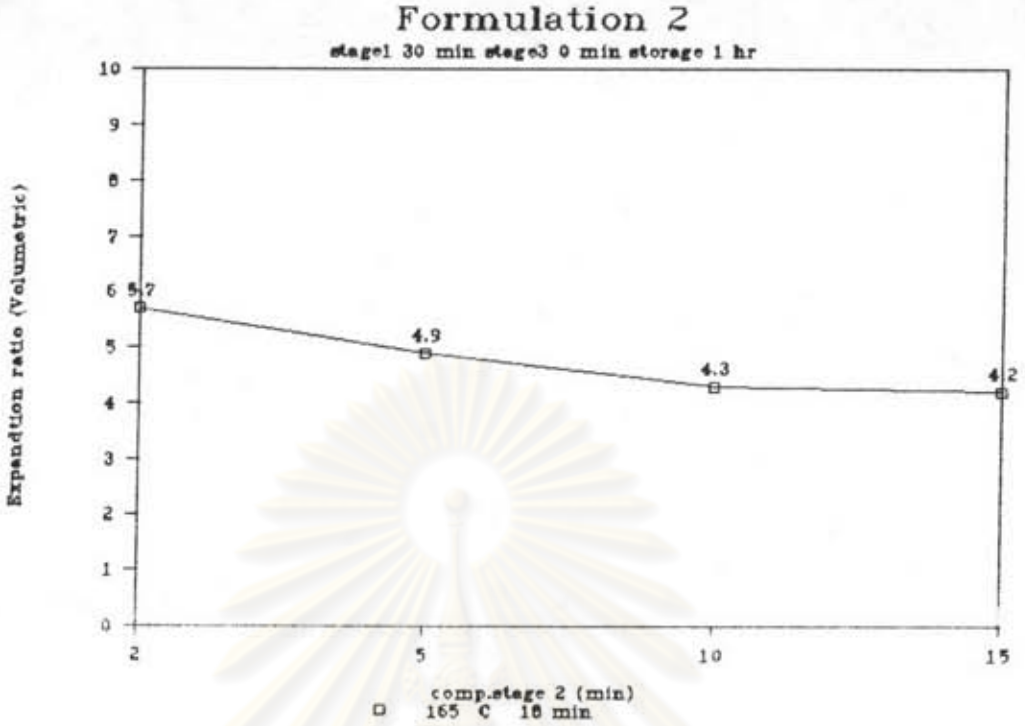


Figure 4.25 Effect of stage 2 compounding time on expansion ratio.

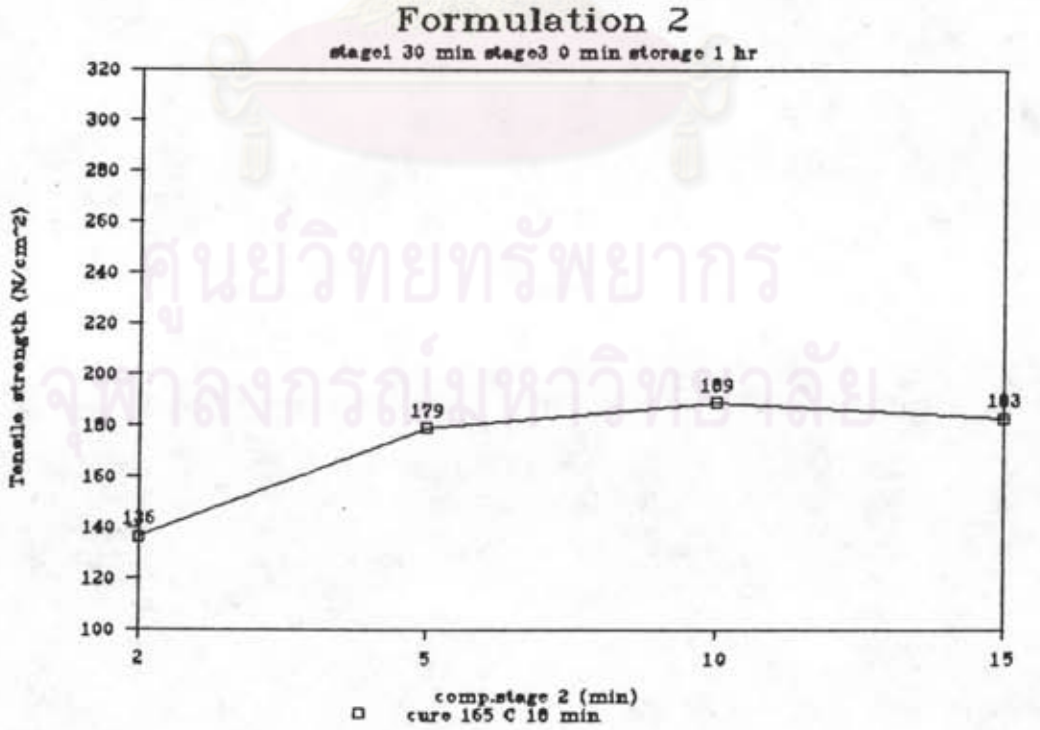


Figure 4.26 Effect of stage 2 compounding time on tensile strength.

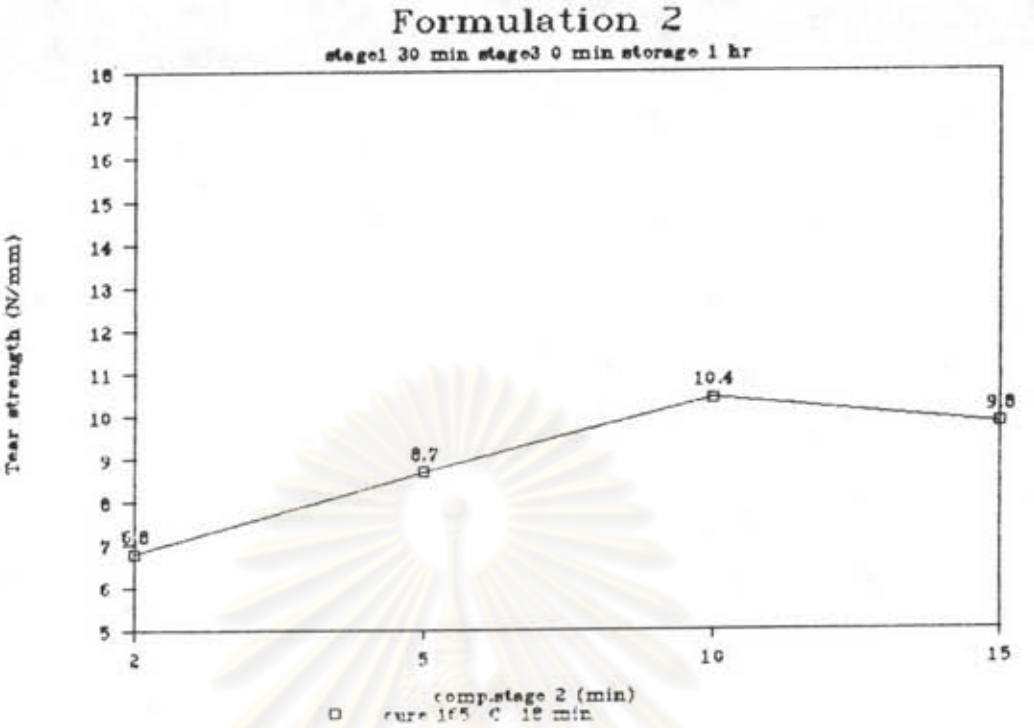


Figure 4.27 Effect of stage 2 compounding time on tear strength.

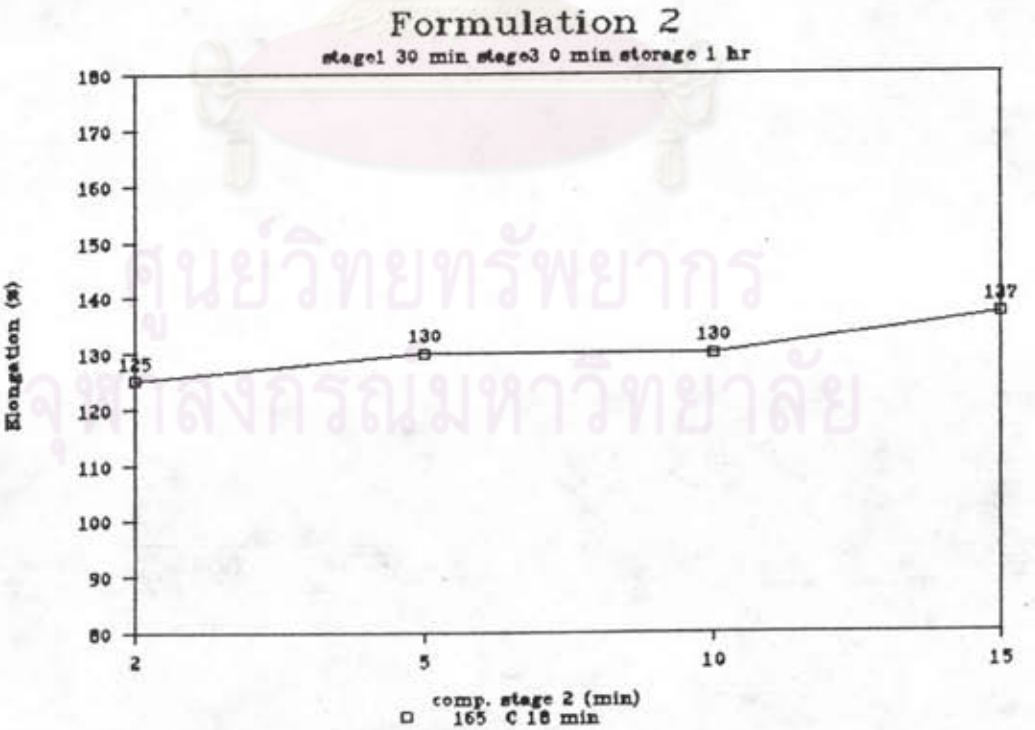


Figure 4.28 Effect of stage 2 compounding time on elongation.

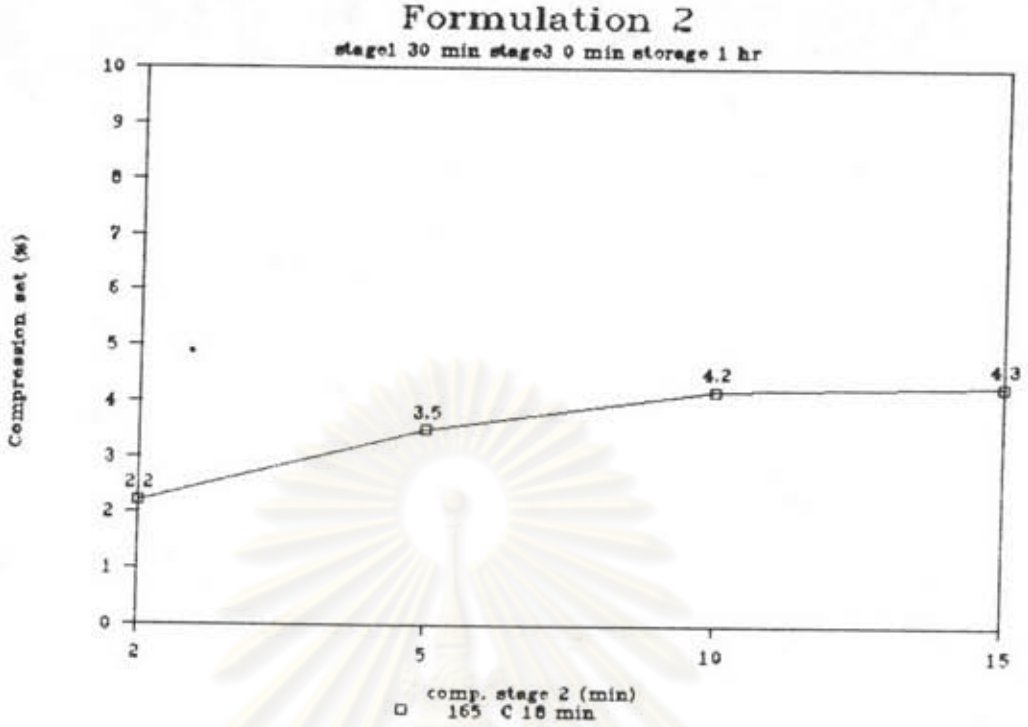


Figure 4.29 Effect of stage 2 compounding time on compression set.

4.2.3 Effect of Stage 3 Compounding Time on Physical Properties

From Table 4.5, the increasing of time interval of compounding stage 3 was shown to case little decrease in various physical properties of the foam. These effects followed the above results in Figure 4.10 and 4.3 that the foaming and the cross-linking were little affected by the time in this stage. The results obtained indicated that this stage can be used as cooling and sheeting of EVA compound but the time used should not be grater than 5 minutes.

Table 4.5 Effect of stage 3 compounding time on physical properties

Compounding stage 3 (min.) Physical Properties	0*	5	10
Density (g/cm^3)	0.16	0.16	0.15
Hardness (Type C)	50	48	47
Expansion ratio (Volumetric)	4.9	4.9	5.2
Tensile strength (N/cm^2)	179	180	166
Tear strength (N/mm)	8.7	9	8.5
Elongation (%)	130	125	120
Compression set (%)	3.5	4.1	4

*Only one sheeting

Formulation 2:

Compounding stage 1	30	min.
Compounding stage 2	5	min.
Storage time	1	hr.
Cure 165°C	18	min.

4.2.4 Effect of Storage Time on Physical Properties

From Table 4.6 and Figure 4.30-4.36, the storage time was shown to have much effect on various physical properties especially between 0-1 hour where all properties, except the expansion ratio, decreased with increasing storage time corresponding to the increasing foaming in this storage period (Figure 4.6). Similarly, the small decreasing behaviour of various properties after 1 hour followed the pattern of the foaming in that period. However, only the storage time between 1 to 3 hours was practical because the foam was small increasing during the interval and the foam with storage time greater than 5 hour had the problems of non-uniform foam size and also very large air bubble, Finally the foam was yellowish colour with odour. Therefore, the storage time of one hour was used in the study because it was practical.

Table 4.6 Effect of storage time on physical properties

Physical Properties \ storage time (hr)	0*	1	3	18
Density (g/cm^3)	0.19	0.15	0.14	0.12
Hardness (Type C)	54	47	43	35
Expansion ratio (Volumetric)	4.3	5.2	5.4	7.1
Tensile strength (N/cm^2)	199	163	162	140
Tear strength (N/mm)	10.1	8.5	7.7	6.2
Elongation (%)	135	120	122	122
Compression set (%)	6.3	4	1.9	0.4

* 15 min

Formulation 2:

Compounding stage 1	30	min
Compounding stage 2	5	min
Compounding stage 3	10	min
Cure 165°C	18	min

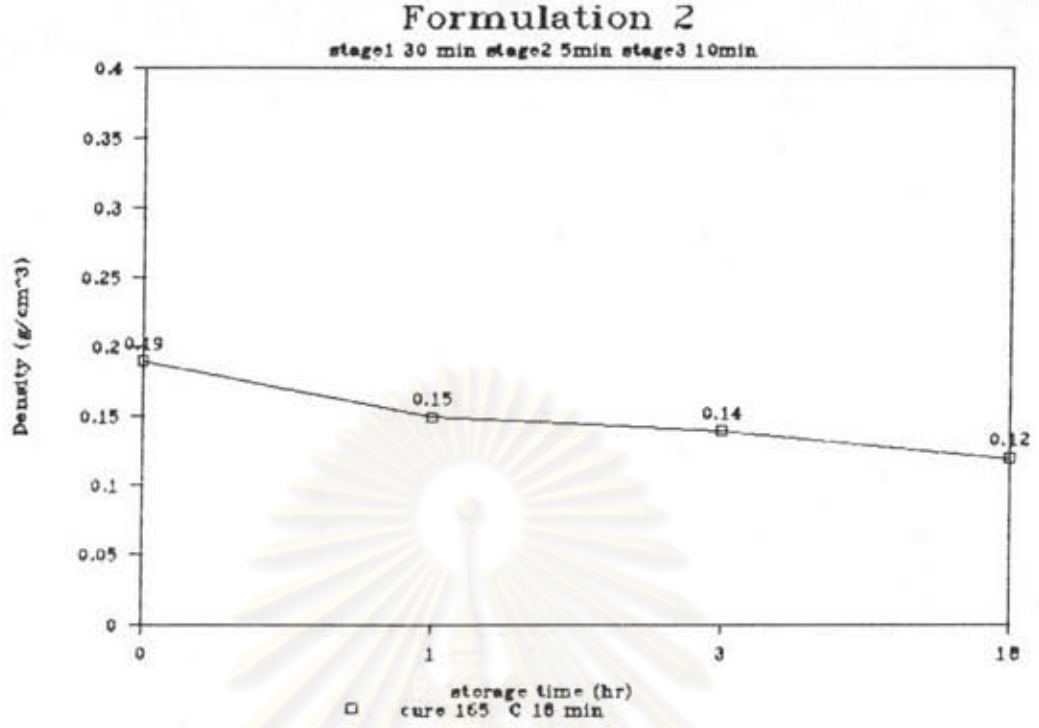


Figure 4.30 Effect of storage time on density.

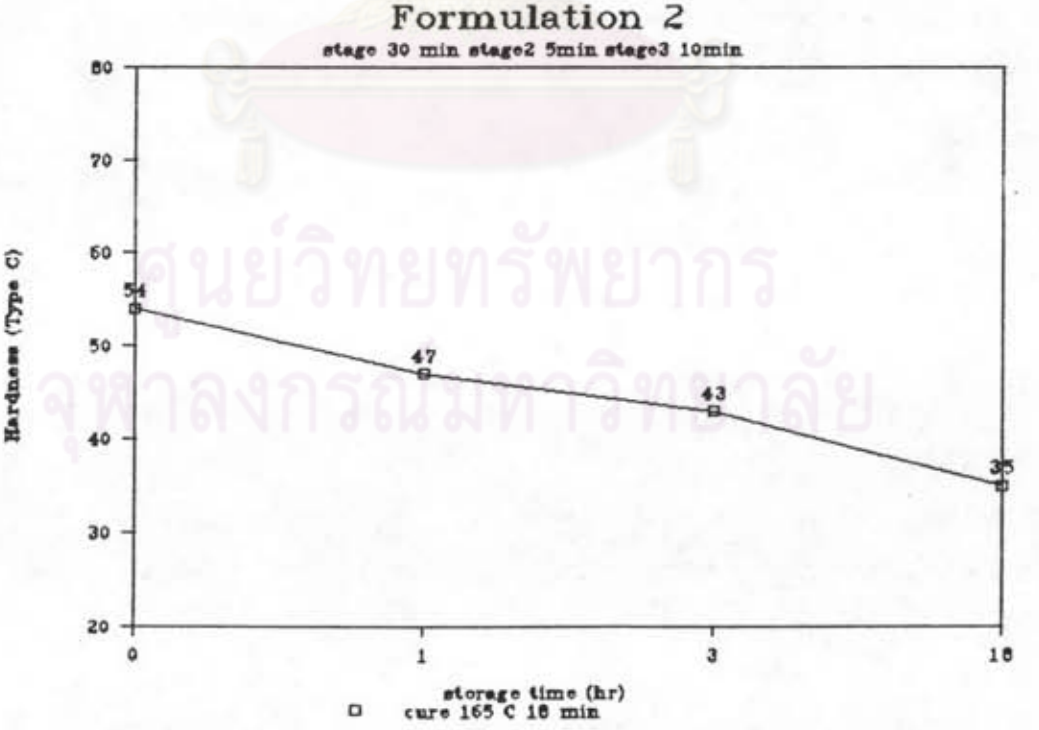


Figure 4.31 Effect of stroage time on hardness.

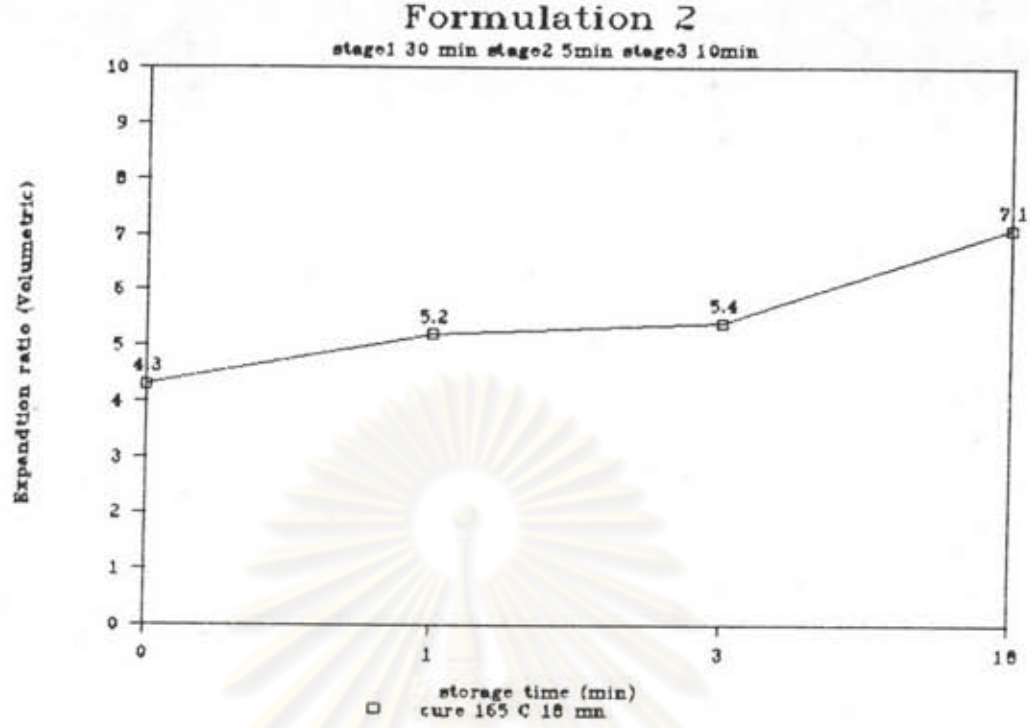
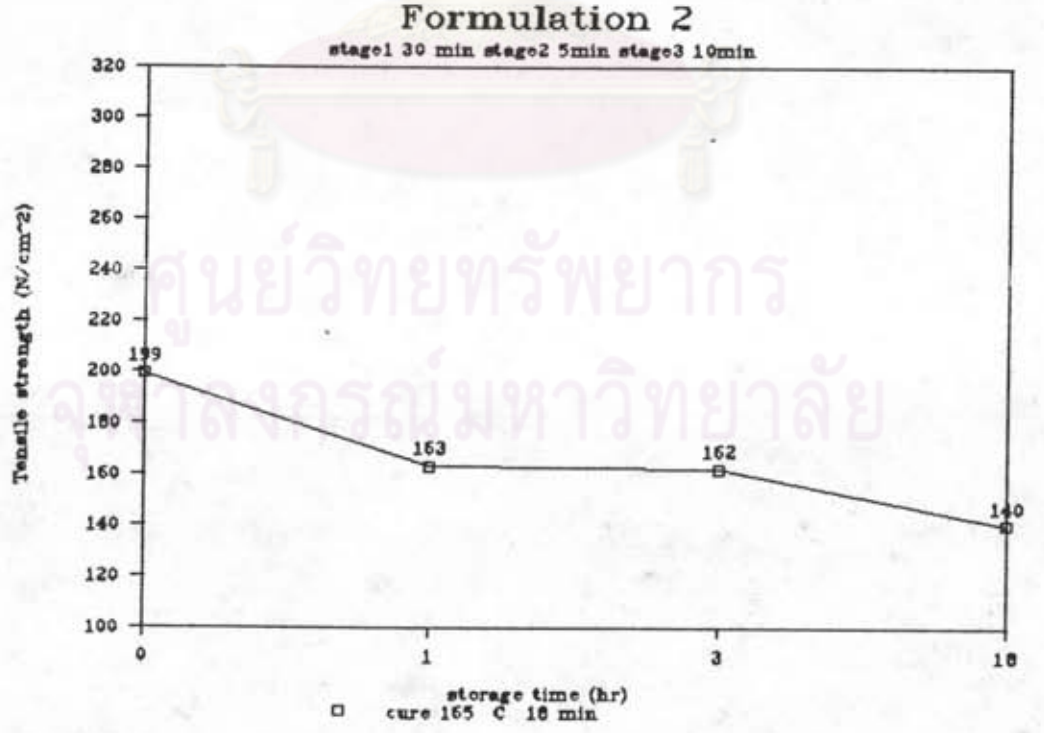


Figure 4.32 Effect of stroage time on expansion ratio.



Figute 4.33 Effect of storage time on tensile strength.

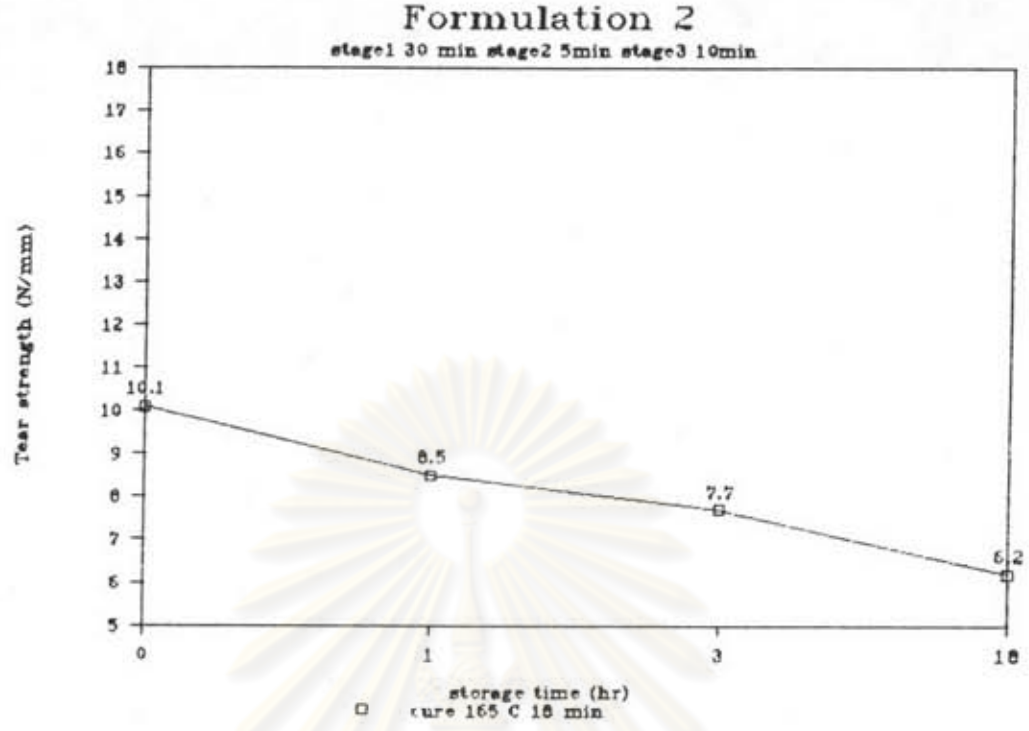


Figure 4.34 Effect of storage time on tear strength.

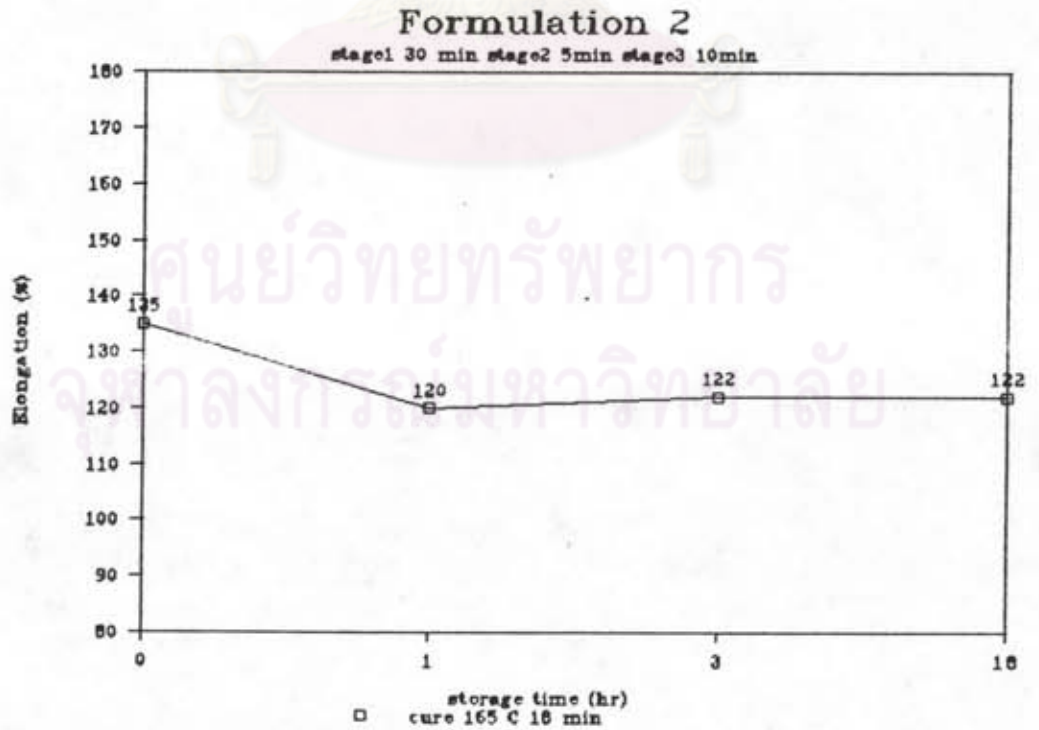


Figure 4.35 Effect of storage time on elongation.

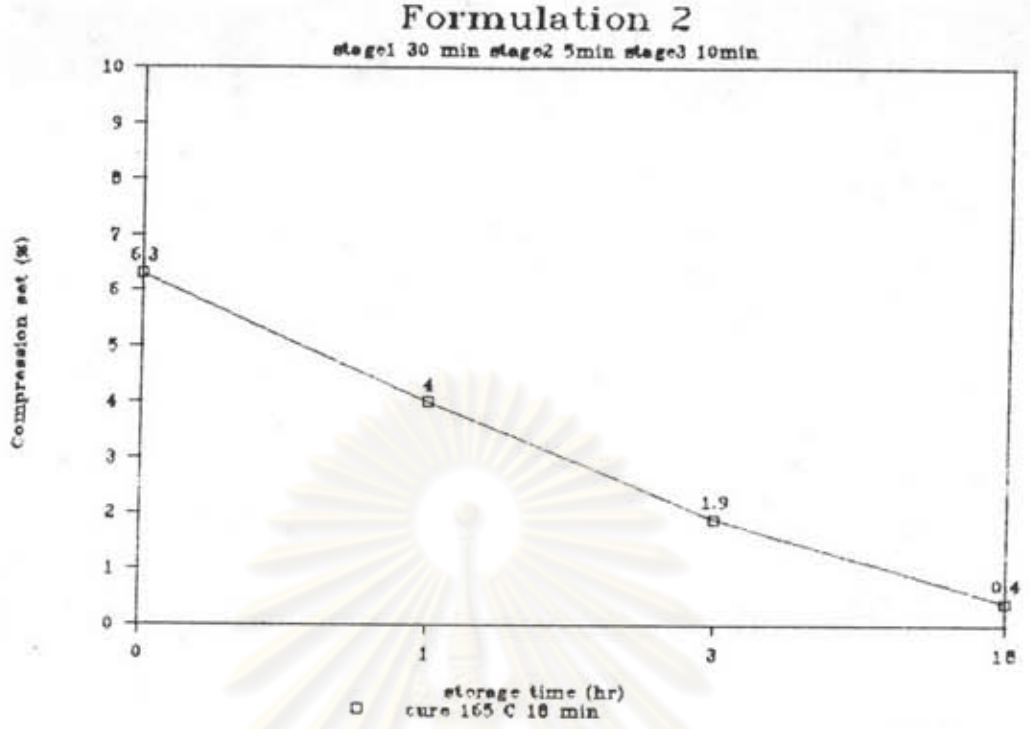


Figure 4.36 Effect of storage time on compression set.

4.2.5 Effect of Cure Temperature on Physical Properties

From Table 4.7 and Figure 4.37-4.43,at cure temperature 185^{o}C, all physical properties, except the expansion ratio, decreased with the increasing cure time and became constant after 7 minutes. At cure temperature 165^{o}C,the physical properties also decrased and became constant after 23 minutes. But the compression set and elongation at cure temperature 185^{o}C was higher than at cure temperature 165^{o}C. Consequently, the cure temperature and the cure time could be adjusted properly to satisfy the required physical properties of the final product. But the compression set at cure temperature 185^{o}C was higher than at cure temperature 165^{o}C. From the photograph of the cells showed that the cells were uniform and spherical in shape at cure temperature 165^{o}C and were squeeze and non-uniform at cure temperature 185^{o}C (Appendix G).

From these result the cure temperature at 165^{o}C was used to study in next step.Because the general properties of the foam are better and can be controled surely.

Table 4.7 Effect of cure temperature on physical properties

Physical Properties	Cure time (min.) / Cure temp °C.	5	7	10	13	18	23	28
Density (g/cm^3)	165				0.19	0.15	0.13	0.12
	185	0.20	0.13	0.12				
Hardness (Type C)	165				53	47	41	40
	185	55	39	39				
Expansion ratio (Volumetric)	165				4.3	5.2	5.9	6.2
	185	4	6.6	6.6				
Tensile strength (N/cm^2)	165				194	163	147	138
	185	190	147	130				
Tear strength (N/mm)	165				10.2	8.5	7.2	6.8
	185	11.7	6.9	5.9				
Elongation (%)	165				150	120	117	115
	185	145	137	137				
Compression set (%)	165				5.3	4	1.9	1.4
	185	5.8	4.6	4.8				

Formulation 2: Compounding stage 1 30 min.
Componnding stage 2 5 min.
Compounding stage 3 10 min.
Storage time 1 hr.

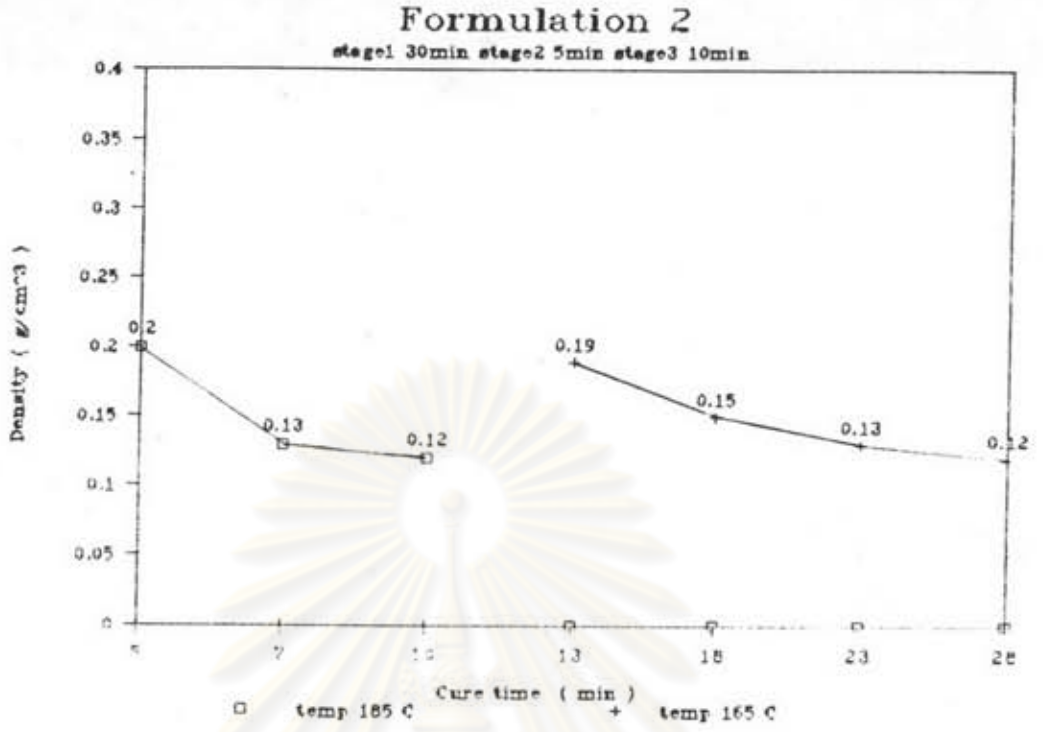


Figure 4.37 Effect of cure temperature on density.

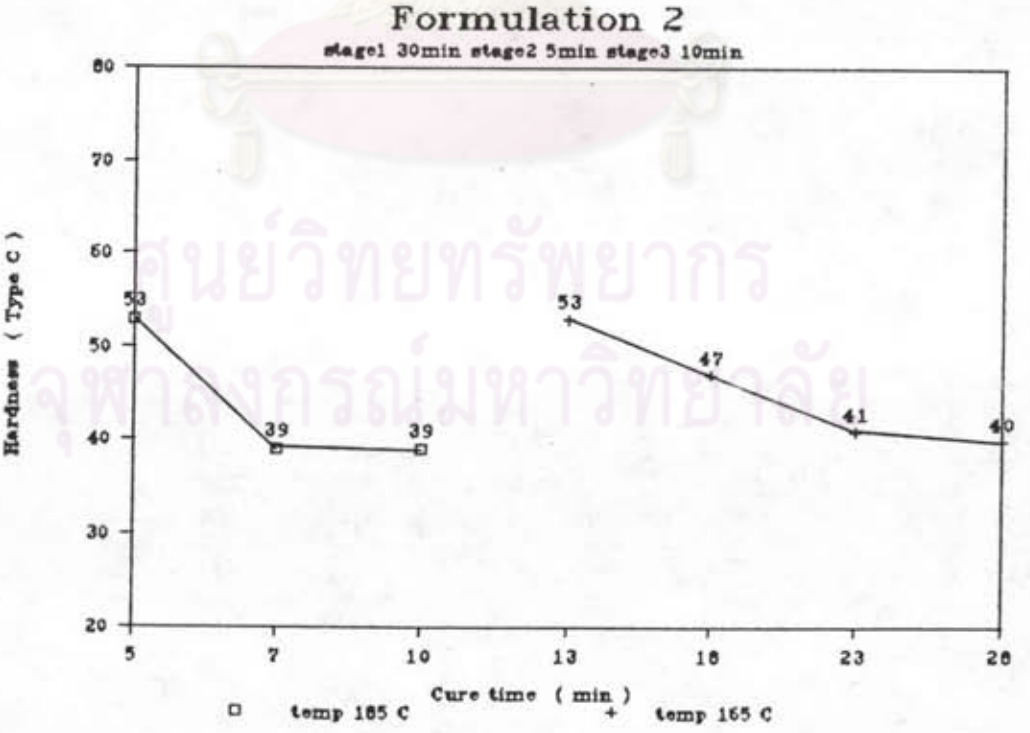


Figure 4.38 Effect of cure temperature on hardness.

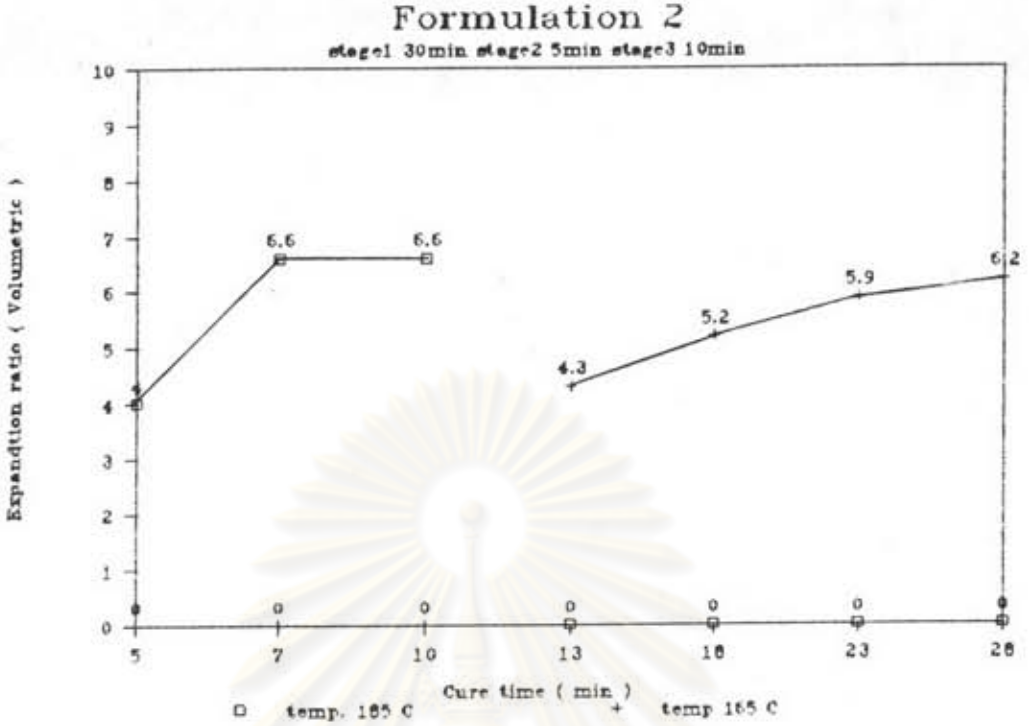


Figure 4.39 Effect of cure temperature on expandtion ratio.

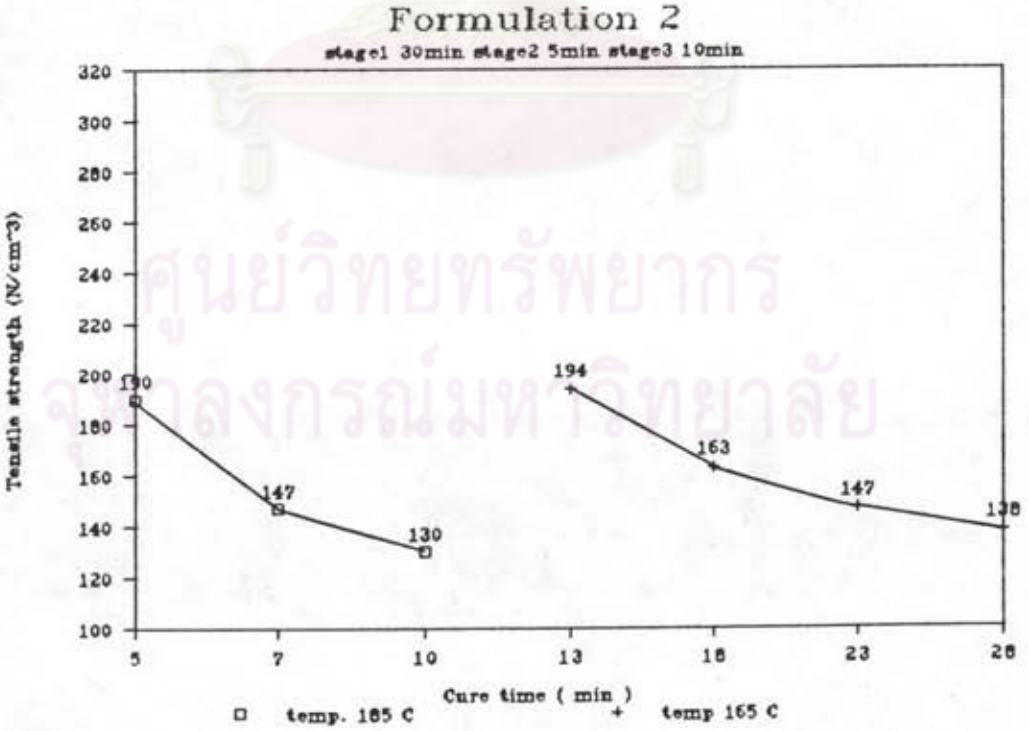


Figure 4.40 Effect of cure temperature on tensile strength.

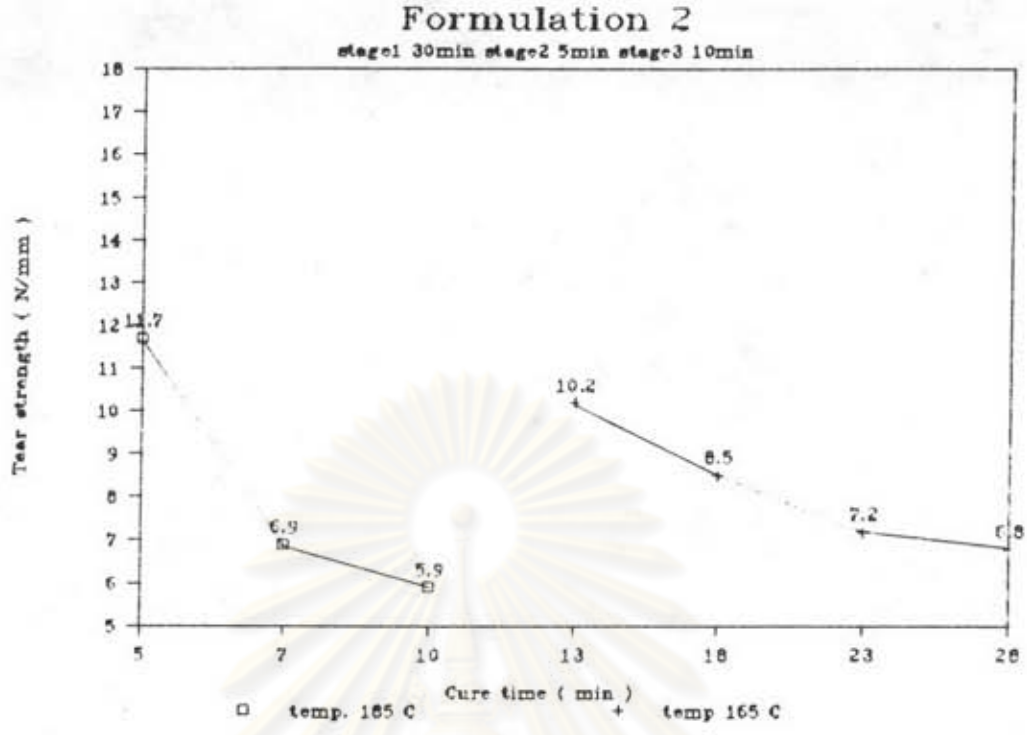


Figure 4.41 Effect of cure temperature on tear strength.

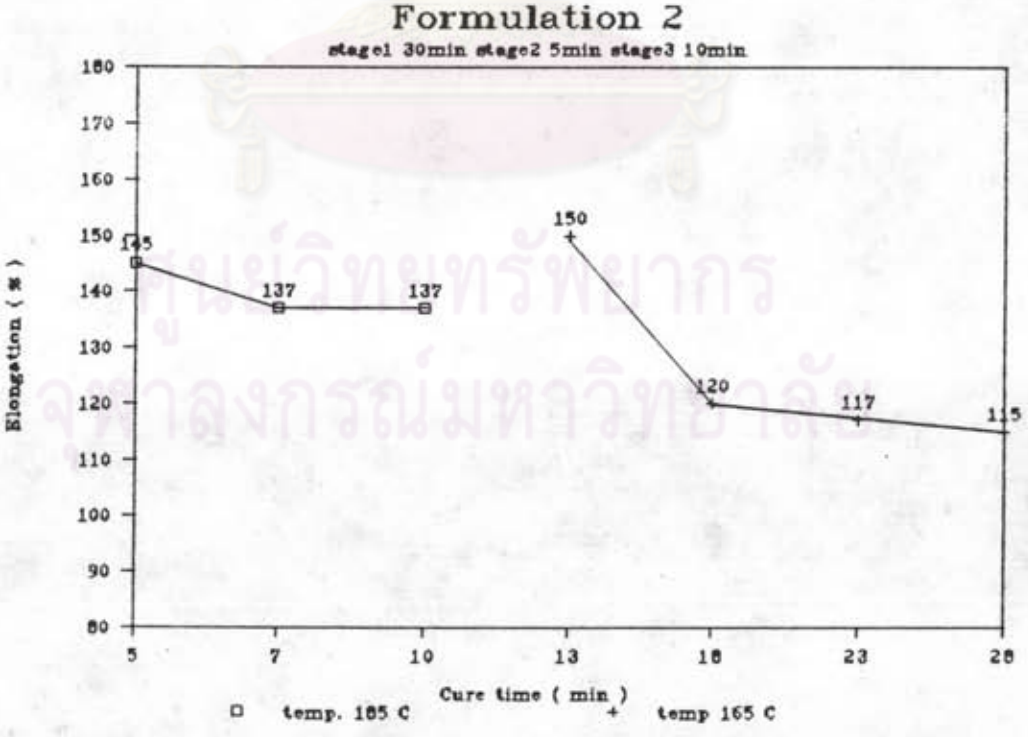


Figure 4.42 Effect of cure temperature on elongation.

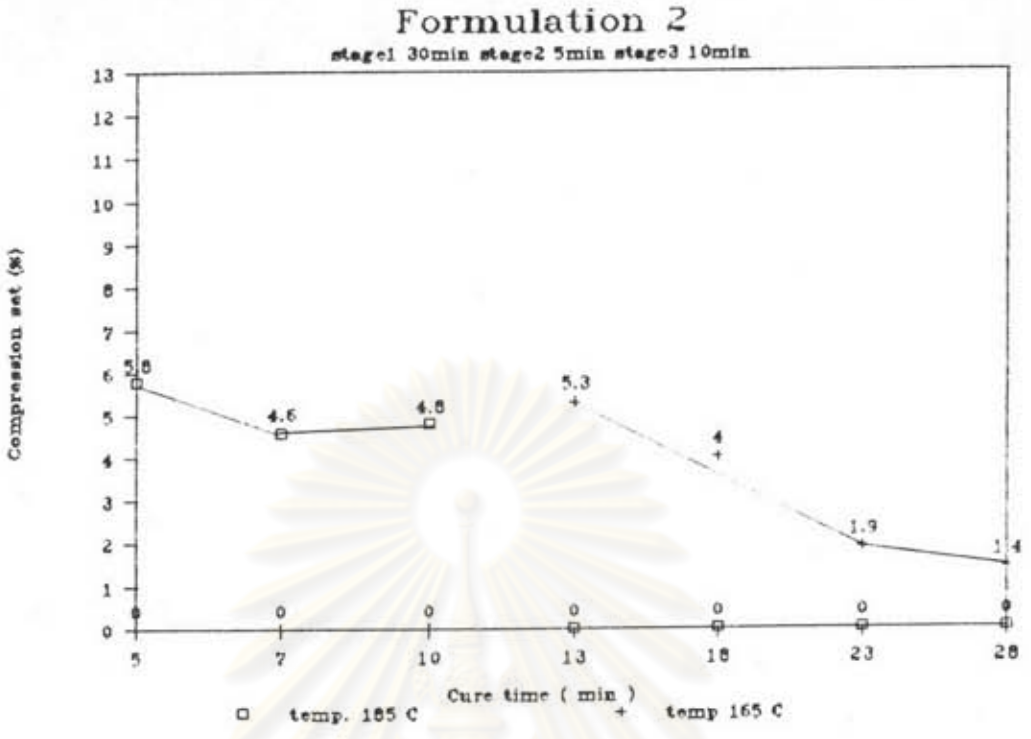


Figure 4.43 Effect of cure temperature on compression set.

4.2.6 Efffect of Cure Time and Level of Blowing Agent on Physical Properties

From Table 4.8 and Figure 4.44-4.50, the various physical properties, except the expansion ratio, decreased with the increasing amount of the blowing agent. Such results followed the effect of the blowing agent on foaming (Figure 4.5). On the other hand, all properties decreased with the increasing cure time and became constant or had little change at some point where, in comparing with Figure 4.5, the foaming did not change, in Figure 4.12, the cross-linking was little increase. From Figure 4.44-4.50, the time when all the above effects at different level of blowing agent began was about 23 minutes. From Figure 4.50, the compression set of the foam (AK#2 2.5 phr) that cure for 28 minutes was increased because the cells were squeeze and open. Similarly, the compression set of the foam (AK#2 8 phr) was also increased because the cells were expanded rapidly until they were open.(as shown in Appendix F1,F2)

From these results, the suitable cure time at temperature 165^{o}C was not above 23 minutes because the physical properties of the foam that cured below 23 mintues were better and it was safety for control the quanlity of the foam that formulated with different level of blowing agent. Other result of the increasing cure time was yellowish colour with odour.

Table 4.8 Effect of cure time and level of blowing agent on physical properties

Physical Properties	Cure time (min.) / Level of AK#2 (phr)	13	18	23	28
Density (g/cm^3)	2.5	0.31	0.28	0.27	0.24
	5	0.19	0.15	0.13	0.13
	8	0.12	0.12	0.11	0.09
Hardness (Type C)	2.5	75	70	68	63
	5	53	47	41	40
	8	43	33	31	27
Expansion ratio (Volumetric)	2.5	2.5	2.6	2.9	3.4
	5	4.3	5.2	5.9	6.2
	8	5.7	6.8	7.3	8.6
Tensile strength (N/cm^2)	2.5	314	260	266	247
	5	194	163	147	138
	8	155	126	115	110
Tear strength (N/mm.)	2.5	17.6	16.5	15	14
	5	10.2	8.5	7.1	6.6
	8	7.7	6.3	5.7	5.3
Elongation (%)	2.5	173	146	150	160
	5	150	120	117	115
	8	132	113	103	110
Compression set (%)	2.5	7.4	5.6	5.8	7.7
	5	5.3	4	1.9	1.4
	8	3.2	1.6	1.5	3

Formulation 1,2,3 :

Compounding stage 1	30	min.
Compounding stage 2	5	min.
Compounding stage 3	10	min.
Storage time	1	hr.
Cure temperature	165	^oC.

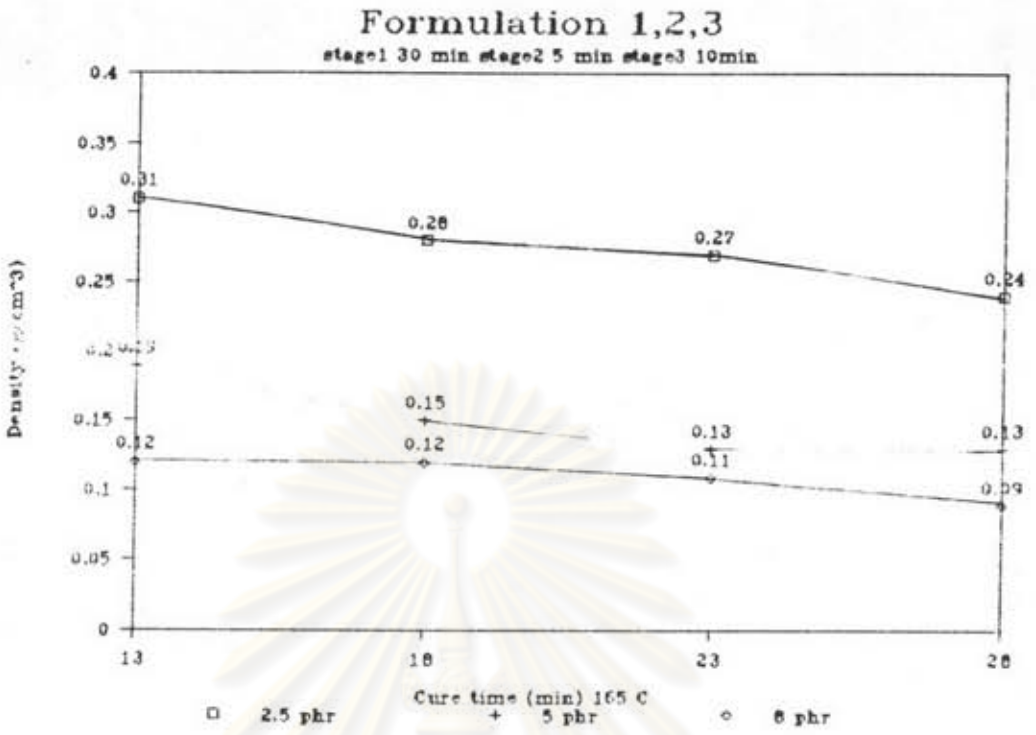


Figure 4.44 Effect of cure time and level of blowing agent on density.

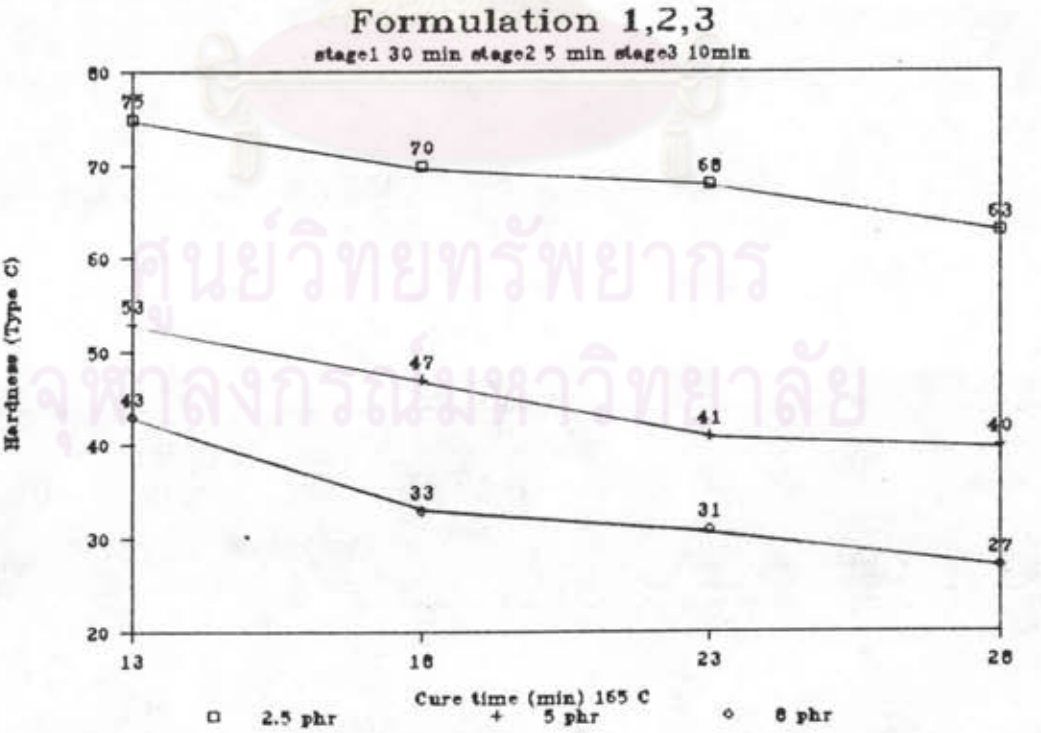


Figure 4.45 Effect of cure time and level of blowing agent on hardness.

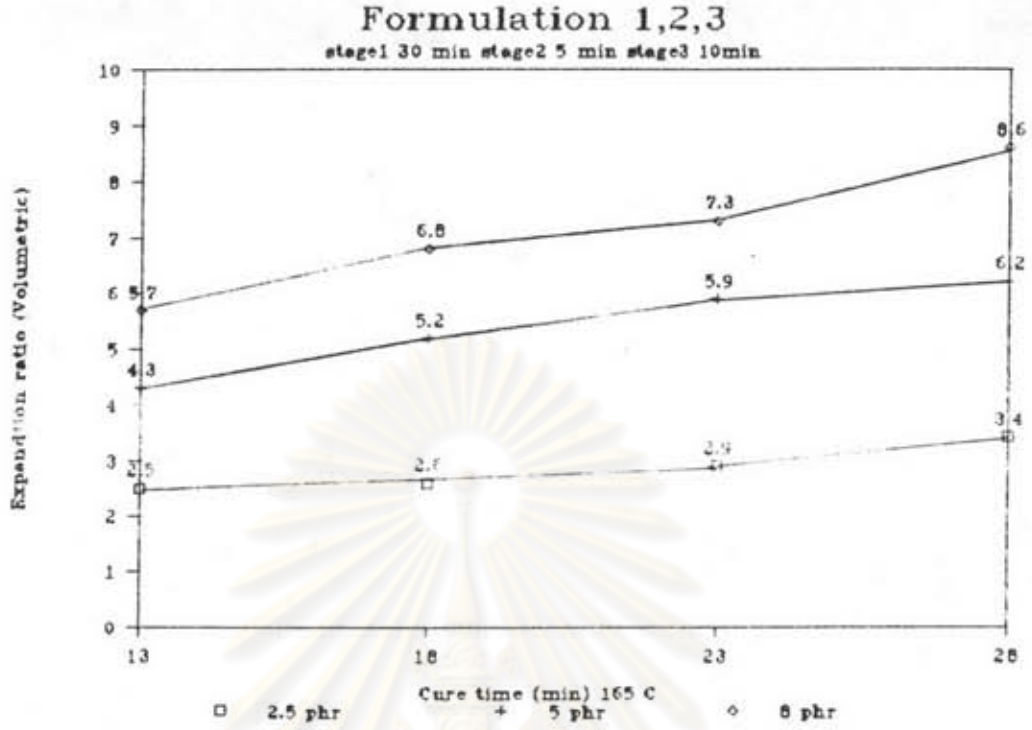


Figure 4.46 Effect of cure time and level of blowing agent on expansion ratio.

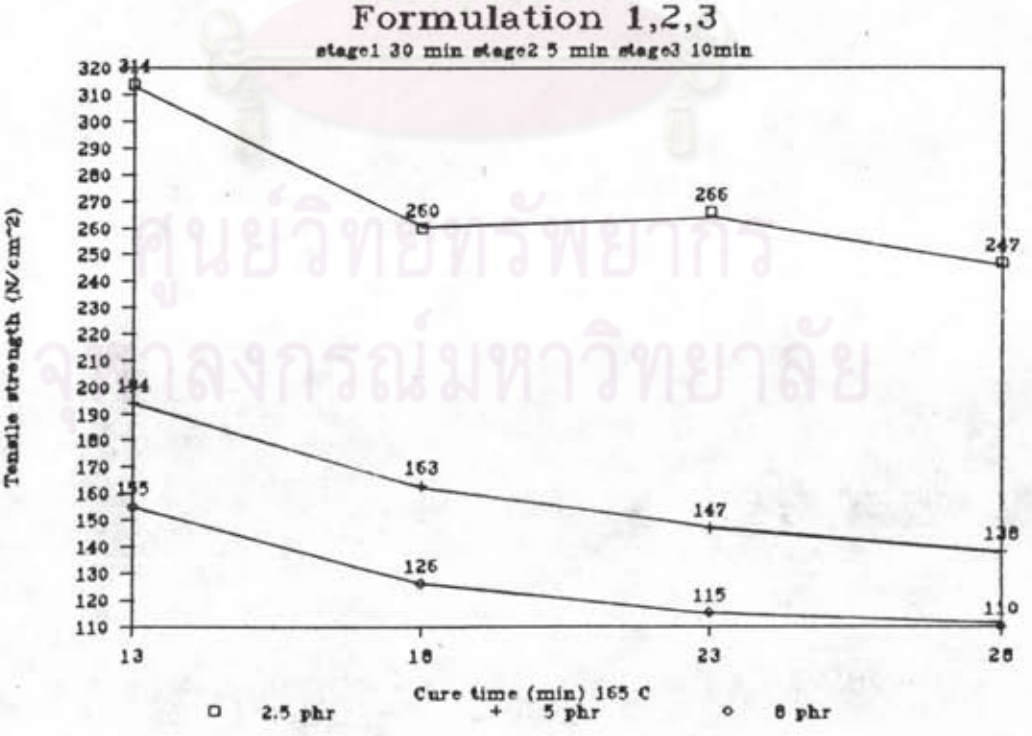


Figure 4.47 Effect of cure time and level of blowing agent on tensile strength.

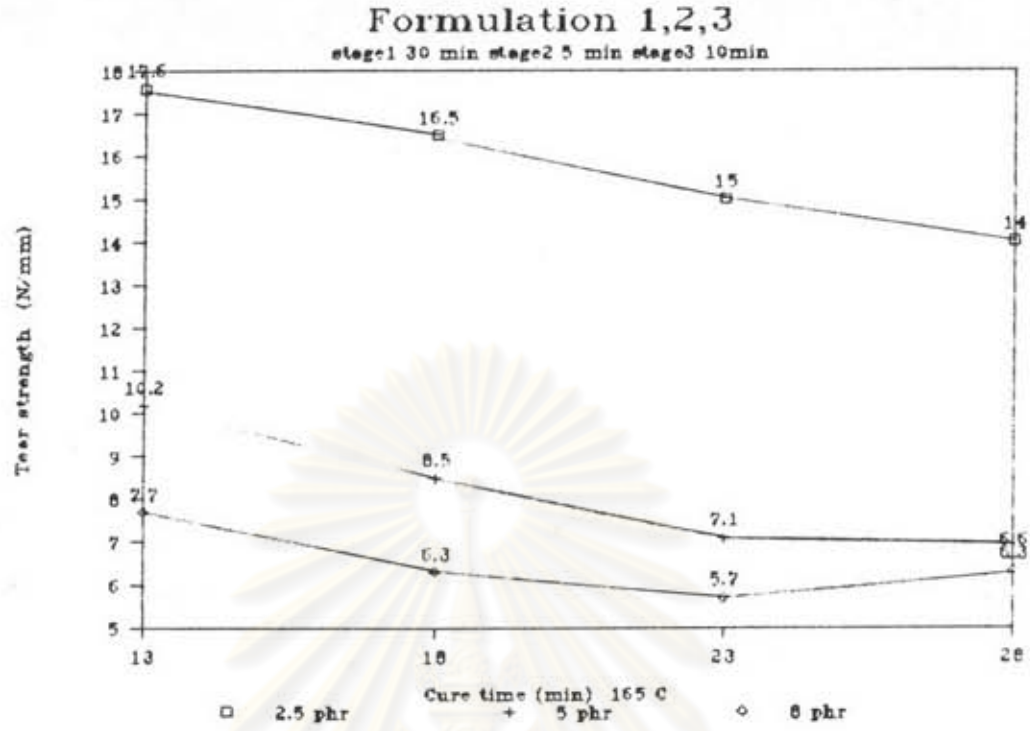


Figure 4.48 Effect of cure time and level of blowing agent on tear strength.

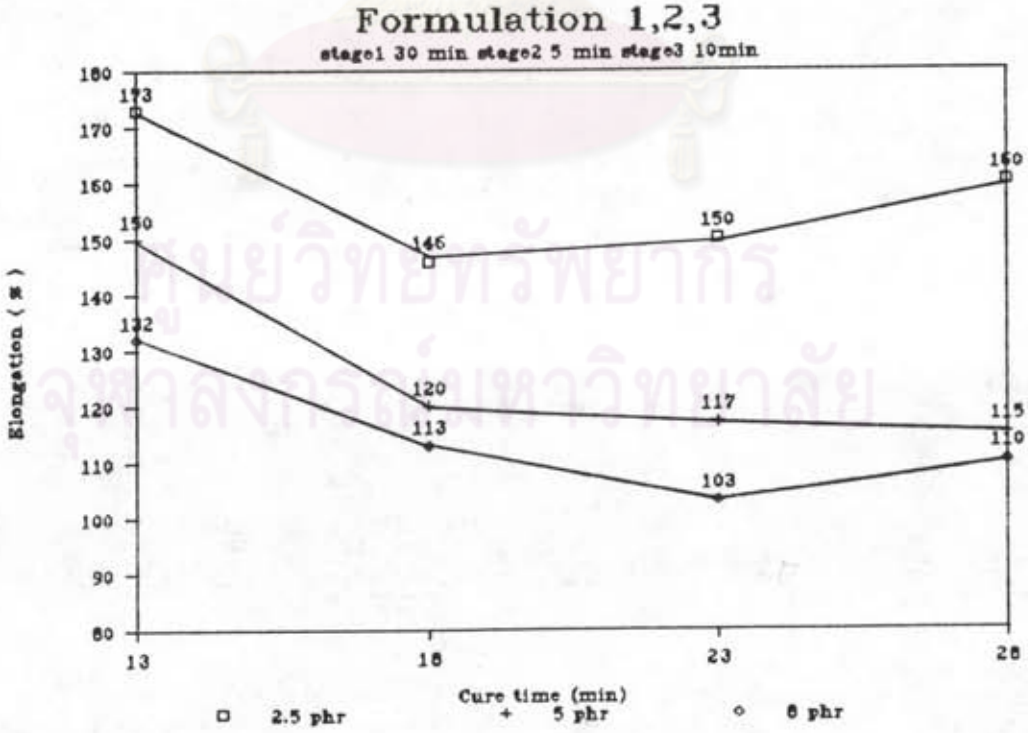


Figure 4.49 Effect of cure time and level of blowing agent on elongation.

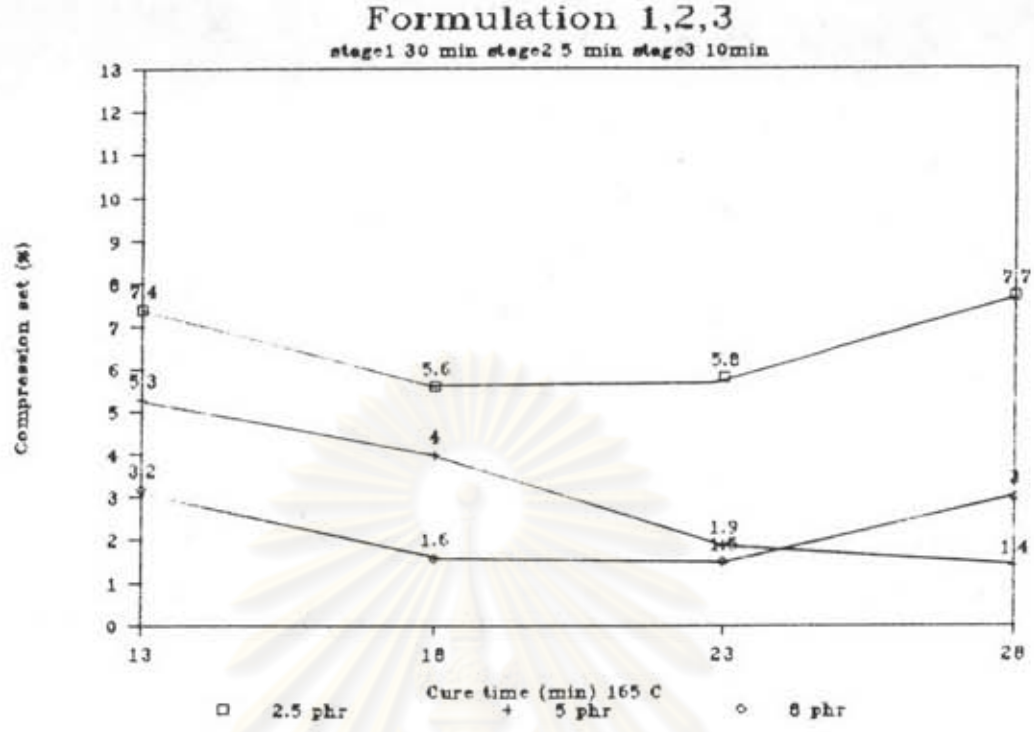


Figure 4.50 Effect of cure time and level of blowing agent on compression set.

4.2.7 Effect of Amount of Zinc Oxide on Physical properties

From Table 4.9, at cure temperature 185°C, the increasing amount of zinc oxide increased only tensile strength, tear strength and elongation where the other properties were rather constant. However, at cure temperature 165°C, all physical properties increased constantly with the amount of zinc oxide. According to Figure 4.11,the amount of zinc oxide effected only the cross-linking but had no effect on the blowing,as shown in Figure 4.4. Therefore, the increasing properties were possibly caused by the high cross-linking. And the photography of the cells showed that zinc oxide was used as nucleating agent and the cells were very uniform and sphecical in shape. The amount of zinc oxide had an increasing affect on compression set in one cure period and a decreasing effect at another period (Table 4.9). The increasing of compression set was effect by the cells were squeeze and open (Appendix H1,H2).

The results showed that the amount of zinc oxide must be mixed in the compouned of EVA foam for improved the physical properties and solved the problem of odour and colour. The suitable cure time was below 20 minutes at cure temperature 165°C.

Table 4.9 Effect of amount of zinc oxide on physical properties

Physical Properties	Cure temp. (^{o}c.)	Level of Zno (phr) / Cure time(min.)	0%	8%
Density (g/cm.)	185	5	0.20	0.21
		7	0.16	0.15
	165	18	0.15	0.19
		23	0.13	0.17
Hardness (Type C)	185	5	55	58
		7	48	47
	165	18	47	54
		23	41	49
Expansion ratio (Volumetric)	185	5	4	4
		7	5.6	5.3
	165	18	5.2	4.2
		23	5.9	5
Tensile strength (N/cm.)	185	5	146	191
		7	147	166
	165	18	163	178
		23	147	165
Tear strength (N/mm)	185	5	11.7	11.5
		7	7.2	8.5
	165	18	8.5	10.3
		23	7.1	8.4
Elongation (%)	185	5	137	166
		7	120	137
	165	18	120	142
		23	117	110
Compression set (%)	185	5	5.8	3.3
		7	3.1	4.3
	165	18	4	3.1
		23	1.9	4.5

Formulation 2,6 : Compounding stage 1 30 min.
Compounding stage 2 5 min.
Compounding stage 3 10 min.
Storage time 1 hr.

4.2.8 Optimum Condition of Foaming Process of EVA Rubber

1) Compounding Stages

-Stage 1. With the uniform distribution of the compounding, checking from the constant shear viscosity period, all physical properties were rather constant, except the compression set at stage 1 compounding time 30 minutes was decreased.

-Stage 2.The longer time in this period affected the decomposition of the blowing agent and therefore decreased the foaming. So,the result affected the physical properties.

-Stage 3. This period had little effect on various physical properties. It can be regarded as cooling and sheeting period.

2) Storage Stage

The storage time had much influence on physical properties of the final EVA foam. Therefore, the decreasing effect of various properties resulted from the increasing foaming for a longer time.

3) Cure Time/Temperature

These two closely related parameters were very important in controling the cross-linking /foaming of the system and therefore proper adjustment of them is

required to produced the foam with good physical properties. However, the foam properties will become constant when the mechanism in cross-linking/foaming was unchanged.

4) Blowing Agent

This parameter is the most critical one in determining the final properties of the foam. The increasing foaming rate, by adding up the blowing agent, can be used to adjust the physical properties.

5) Zinc Oxide

The substance increased all the foam properties, except the decreasing of compression set which was the required property of the product, but the cure time/temperature must be selected properly.

Summerize the suitable process condition of EVA foaming process according to this investigation:

-Compounding stage 1	30	min
-Compounding stage 2	5	min
-Compounding stage 3	5	min
-Storage stage	1	hr
-Cure 165^{o}C	13 - 20	min

Other process conditions were fixed as shown in Chapter III.

4.3 Replacement of Synthetic Polyisoprene by Natural Rubber in Foaming Process of EVA Blends

All process parameters that affected the foaming process were studied again in this step. From the results in section 4.1 and 4.2, Various parameters were listed below.

-Shear viscosity in the compounding stage 1.
-Time in the compounding stage 2 was fixed at 5 minutes.
-Time in the compounding stage 3 was fixed at 5 minutes.
-The storage time was 1 hour.
-The cure time was determined from the cross-linking/foaming at cure temperature 165^{o}C

4.3.1 Effect of Stage 1 compounding time on Shear Viscosity

The formulation that contained natural rubber or synthetic polyisoprene 15 phr was used to determine the shear viscosity. From Fig. 4.51, the shear viscosity was shown to be constant at about 20-25 minutes. Therefore, the appropriate time in this stage was selected to be between 20-30 minutes,due to the formulation that contained natural rubber or synthetic polyisoprene 5 phr.

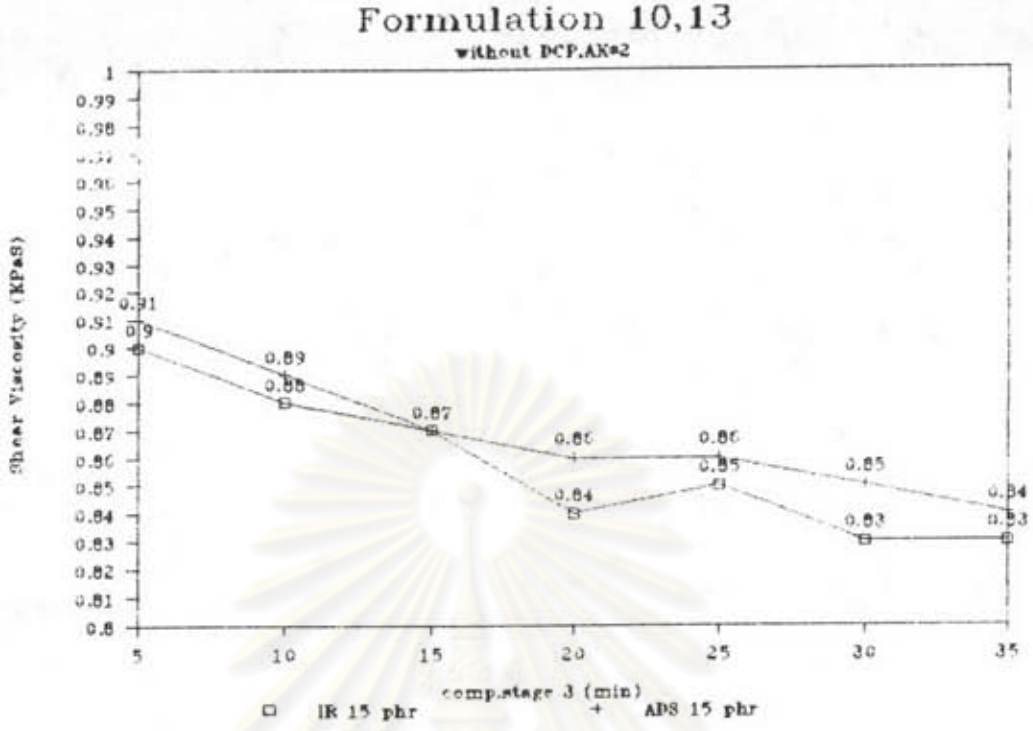


Figure 4.51 Effect of compounding stage 1 on shear viscosity.

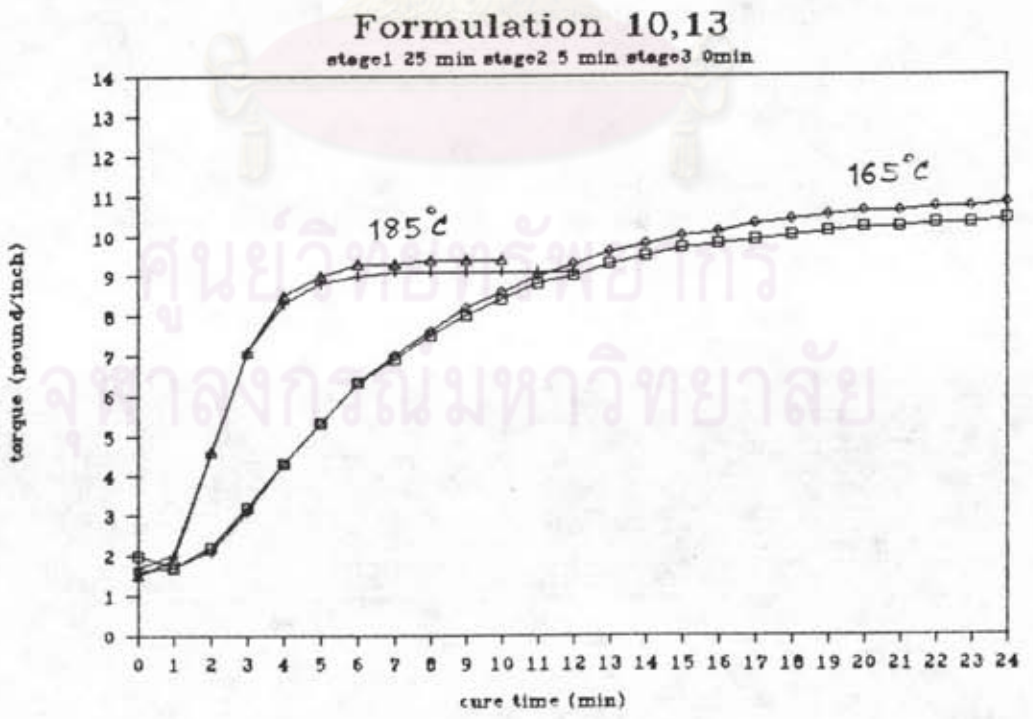


Figure 4.52 Effect of natural rubber and synthetic polyisoprene on cross-linking.

4.3.2 Effect of Synthetic Polyisoprene and Natural Rubber on Cross-linking

From Fig. 4.52, the cross-linking of synthetic polyisoprene compound was a little higher than natural rubber compound at the cure temperatures 165°C. However, the shear viscosity of natural rubber compound was higher than synthetic polyisoprene compound, as shown in Fig. 4.51. So it can be concluded that the impurity in natural rubber rubber was the main problem in retarding the corss-linking of the compound. The 90 percent cross-linking time was 15 minutes at cure temperature 165°C and used to define the minimum cure time for the cross-linking.

4.3.3 Effect of Synthetic Polyisoprene and Natural Rubber on Foaming

The foaming of synthetic polyisoprene compound was shown to be slightly higher than natural rubber compound at cure temperatures 165°C. (as shown in Figure 4.53). Such effect may be caused by some possible volatile ingredients existing in the synthetic polyisoprene. The decomposition of blowing agent began to be small increasing at about 14 minutes and the time was used to determine the foaming time.

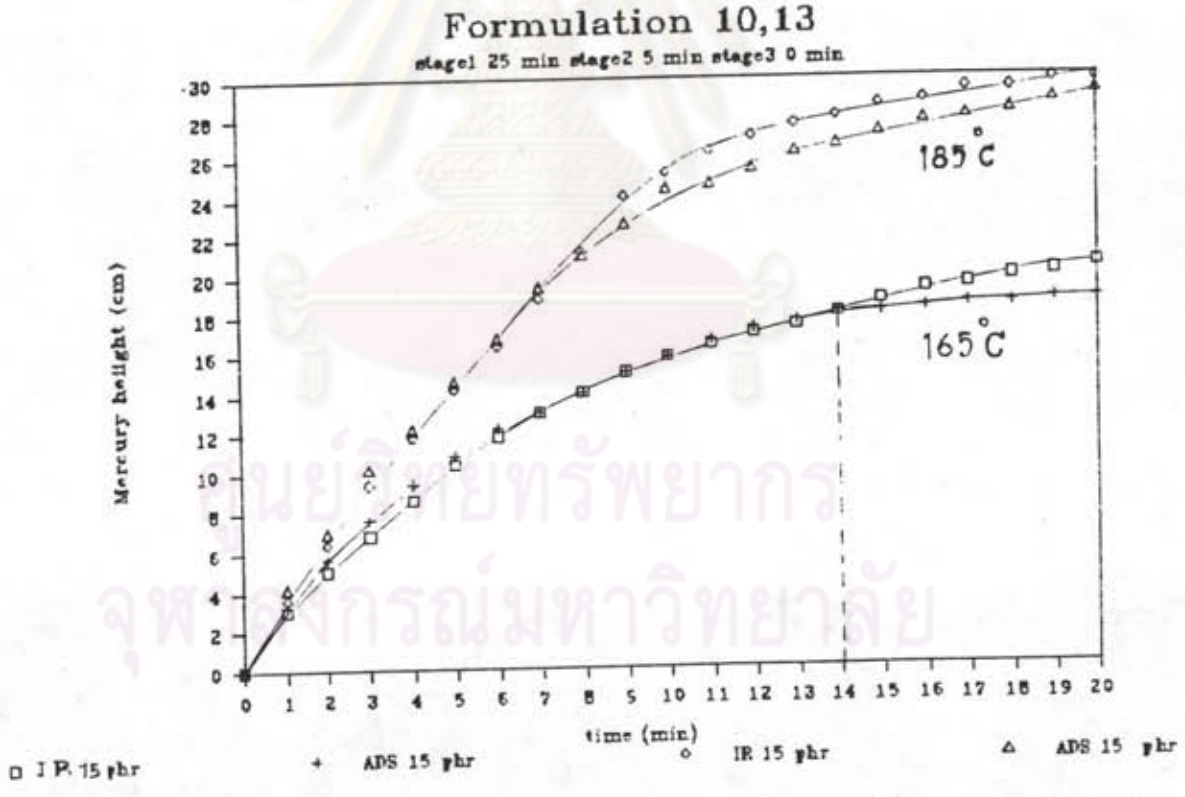


Figure 4.53 Effect of natural rubber and synthetic polyisoprene on foaming.

4.3.4. Efeect of Level of Synthetic Polyisoprene and Stage 1 Compounding Time on Physical Properties

From Table 4.10, the increasing amount of synthetic polyisoprene caused little decrease in various physical properties, except the elongation. The stage 1 compounding time between 20-30 minutes had little affect on various physical properties owing to the uniform distribution of the compounds that formulated with the difference level of synthetic polyisoprene (5,10,15 phr.).

4.3.5 Effect of Level of Natural Rubber and Stage 1 Compounding Time on Physical Properties

From Table 4.11, the various physical properties were shown to decrease slightly with the increasing level of natural rubber, except the elongation. The time interval in compounding stage 1 between 25-30 minutes caused little changes on various properties owing to the uniform distribution of the compounds (natural rubber 5,10,15 phr.).

Table 4.10 Effect of level of synthetic polyisoprene and stage 1 compounding time on pysical properties

Formulation no.	physical Properties Stage 1 time (min)	Density (g/cm^3)	Hardness (Type C)	Expansion ratio (Volumetric)	Tensile strength (N/cm^2)	Tear strength (N/mm)	Elongation (%)	Compression set (%)
	20	0.16	44	5	163	8.4	150	2.9
8	25	0.16	45	5.9	159	8.3	140	4.1
(IR 5 phr)	30	0.16	48	5.3	161	8.5	150	3.4
	20	0.16	43	5	151	8.5	152	2.7
9	25	0.14	41	5.9	145	8	152	3.7
(IR 10 phr)	30	0.15	41	6.3	156	8.7	155	3
	20	0.15	40	5	151	8.5	163	2.1
10	25	0.15	41	5.3	158	8.1	157	3.9
(IR 15 phr)	30	0.15	41	5.7	143	7.8	166	3.2

Compounding stage 2	5	min
Compounding stage 3	5	min
Storage time	1	hr
Cure 165°C	18	min

Table 4.11 Effect of level of natural rubber and stage 1 compounding time on physical properties

Formulation no.	physical Properties Stage 1 time (min.)	Density (g/cm^3)	Hardness (Type C)	Expansion ratio (Volumetric)	Tensile strength (N/cm^2)	Tear strength (N/mm)	Elongation (%)	Compression set (%)
	20	0.16	43	5.3	151	7.6	136	2.5
11	25	0.14	41	6	154	7.8	133	4.6
(ADS 5 phr)	30	0.15	45	5.7	153	7.8	132	4.2
	20	0.17	44	4.6	158	8.6	153	2.3
12	25	0.14	38	5.7	145	7.8	146	2
(ADS 10 phr)	30	0.14	40	5.8	147	7.9	145	3.6
	20	0.16	43	4.6	159	8.4	165	2.2
13	25	0.14	36	5.7	140	7.4	163	4.9
(ADS 15 phr)	30	0.14	39	5.7	139	7.3	153	2.8

Compounding stage 2	5	min.
Compounding stage 3	5	min.
Storage time	1	hr.
Cure 165°C.	18	min.

4.3.6 Comparison of Physical Properties of Synthetic Polyisoprene and Natural Rubber in Foaming Process of EVA Blends

From Table 4.10 and 4.11,the results showed that all properties of the foam(synthetic polyisoprene blend) were slightly higher than the foam (natural rubber blend)at the same ratio. Such effects corresponded with the results in Figure 4.52 where the cross-linking of synthetic polyisoprene compound was slightly higher than natural rubber compound and in Figure 4.53 the foaming of both compound were comparatively the same. From section 4.3.4 and 4.3.5, it was shown that the time for uniform distribution of natural rubber compound (about 25- 30 minutes) was slightly higher than synthetic polyisoprene compound (about 20-25 minutes). Therefore, the time sequired to control the uniformity of both compounds that formulated with difference level of both rubber could be selected to be 25 minutes.

The lower physical properties of natural rubber compound, caused by smaller cross-linking, could be possilble improved by adding the cross-linking into natural rubber compound. From the lab observation, the distiriction between both foam can be seen from the more yellowish color of the foam that blended with natural rubber.

Summerize the suitable condition of foaming process of ethylene vinylacetate/natural rubber blends.

Formulation:

	phr.
Ethylene vinylacetate	90 - 95
Natural rubber	10 - 5
Precipitate silica	10
Coated Calcium Carbonate	6
Stearic acid	0.5
Zinc stearate	1
Zinc oxide	0.4
Blowing agent	Vary
Cross-linking agent	0.9

Process condition:

Compounding stage 1	25	min.
Compounding stage 2	5	min.
Compounding stage 3	5	min.
Storage stage	1	hr.
Cure 165° C	15-20	min.

Other conditions were fixed as shown in chapter III