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AMMRC TR 81-41

TRANSPARENT POLYOLEFIN FILM ARMOR

August 1981

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Garden Grove, California 92645

FINAL REPORT

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Prepared for

ARMY MATERIALS AND MECHANICS RESEARCH CENTER
Watertown, Massachusetts 02172

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ABSTRACT

Block No. 20

The general objective of this project was to determine the optimum processing conditions for the large scale conversion, by molding and laminating of oriented polyolefin film into fragment resistant transparent armor suitable for Army aircraft glazing applications. The manufacturing process must produce a laminate with sufficient adhesion to resist debonding during thermal cycling and yet react as a laminar structure during ballistic impact.

To accomplish the objectives required the completion of the following six major tasks.

- Preparation of reference film and sheet to which all other film and sheet could be compared.
- Effect of film characteristics including evaluation of additional films compared with the reference film and the selection of film for optimization.
- Molding of flat sheet to optimize the molding process.
- Protective covers evaluation and selection.
- Process specifications that describes the selected materials and the procedure for converting the film into molded sheet having the desired properties.
- Production of film and bonded sheet in accordance with the process specifications.

These tasks were accomplished in consecutive order so that a film material or processing condition from one task found to improve transparency and ballistic performance could be used in the next task.

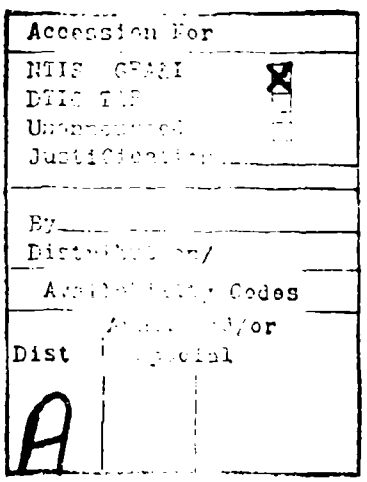
These tasks were successfully performed, in the order listed, and the general objective of this project has been achieved. An optimum process has been established, and in the process, areas of further development have been identified.

FOREWORD

This report covers work performed under contract number DAAG 46-76-C-0034, Amendment Number P000002. This work was performed for the Army Materials and Mechanics Research Center (AMMRC), Watertown, Massachusetts. Mr. Anthony Alesi was the Technical Supervisor.

Acknowledgement is given to Mr. Alesi for his valuable assistance and direction.

In addition, the Swedlow personnel who made significant contributions to the completion of this work are: C. Gibson, J. Peterson, C. Bailey, W. White and W. Harbison.



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EXECUTIVE SUMMARY

This program has demonstrated the manufacturing technology for a laminated polyolefin film transparency yielding ballistic protection equivalent to polycarbonate at considerable weight savings. Technical requirements met by this program include acceptable levels of light transmission, haze, interply strength, surface protection, optical deviation and ballistic performance. Processing parameter limits were identified through statistical designed experimentation. Typical production transparencies have been delivered for evaluation.

INTRODUCTION

In 1976, the Army Materials and Mechanics Research Center, (AMMRC), Watertown, Mass., contracted with Swedlow, Inc. to determine the optimum processing conditions for the large scale conversion, by molding and laminating of oriented polyolefin film, into fragment resistant transparent armor suitable for Army aircraft glazing applications.

The manufacturing process must produce a laminate with sufficient adhesion to resist debonding during thermal cycling and yet react as a laminar structure during ballistic impact. To maintain the ballistic properties of the oriented film requires that the manufacturing process not disturb the orientation, for complete fusion into a homogenous mass degrades the ballistic capabilities.

In addition to supplying the labor and required facilities, Swedlow applied its experience gained as a fabricator of high-quality aircraft transparencies and structural laminates to the development of the manufacturing technology of transparent polyolefin armor.

BACKGROUND

Early work conducted by AMMRC demonstrated the potential application of molded oriented polyolefin as a fragment resistant transparent armor material.

This early work was done by AMMRC using a polyolefin film with a fluid compression rolling orientation of approximately 4.5 : 1, (four and one half times its original length). Such orientation increases the tensile strength from approximately 4800 PSI to 33,000 PSI in the machine direction. The strength in the transverse direction is slightly reduced, from 4800 PSI to 4600 PSI.

To take advantage of this increased directional strength of the oriented film, successive layers of the film are cross-plied at 90°. (Reference 5).

Results of the initial AMMRC studies indicated that molded polyolefin would provide the same level of protection against the .22 caliber 17 grain fragment simulator as polycarbonate at approximately half the weight of polycarbonate. Such potential weight savings is highly attractive for aircraft applications.

PROCEDURE

The program was divided into six major tasks. Each task was performed in consecutive order, as listed, so that a film material or processing from one task found to improve transparency and ballistic performance could be used in the next task.

TASK I - Preparation of Reference Film and Sheet

TASK II - Effect of Film Characteristics

TASK III - Molding Flat Sheet

TASK IV - Protective Covers

TASK V - Process Specifications

TASK VI - Production of Film and Bonded Sheet

The performance levels desired for the oriented polyolefin film and molded panels are shown in Table I. The test methods utilized are also shown in Table I.

All film assembly was conducted in a clean room, class 100,000 or better, in accordance with Federal Standard 209. Clean, disposable, polyethylene gloves were worn at all times when handling the polyolefin film or molded sheet.

TABLE I

FILM AND MOLDED PANEL REQUIREMENTS

Property	Performance Level Desired	Test Method	Applicable Material	
			Film	Molded Panel
Sonic Modulus or Orientation Release Stress	Maximum	ASTM F 89	X	
	Maximum	ASTM D 1504	X	
Haze	<3 percent	ASTM D 1003	X	X
Light Transmission	>85	ASTM D 1003	X	X
Resistance to Debonding	Minimum of 5 Cycles without Debonding	ASTM D 756 (Procedure E, -57C low temperature)		X
Thickness	± 5 percent	ASTM D 374	X	X
Ballistic Resistance (1)	Maximum Ballistic Limit	MIL-STD-662		X
Maximum Deviation of line of sight	<7 minutes of Arc	ASTM D 881-48		X
Interlaminar Shear Strength	None Specified (2)	To be selected by the Contractor (3)		X

(1) Ballistic resistance determined by the Government

(2) Although AMMRC did not specify a performance level, Swedlow established an objective of 1000 PSI minimum.

(3) The test method used is defined in paragraph 4.6.9 of MIL-P-25690 (Reference 10).

Task I - Preparation of Reference Film and Sheet

The objective of this task was the preparation of a reference rolled film and molded sheet representing the current state-of-the-art. The results obtained formed the basis of comparison for materials and processing developed under subsequent tasks.

Hercules N400, roll oriented by American Can to an orientation of 4.5:1, was selected by AMMRC to be the reference film. The film was furnished to Swedlow by AMMRC.

Table 2 shows some of the typical properties of the N400 film before and after roll orientation.

TABLE 2

TYPICAL PROPERTIES HERCULES N-400 FILM

Property	Film Values Unoriented	Oriented(1)
Thickness, Inches	0.005-0.0056	0.0011-0.0013
Tensile Strength, PSI		
Machine Direction	4794	32,620
Transverse Direction	4813	4,600
Elongation, Percent		
Machine Direction	595	29
Transverse Direction	665	655
Light Transmission, %	91.4	93.1
Haze, %	18.4	1.5

(1) Fluid compression rolling orientation, 4.5:1 reduction

A chase mold with inside dimensions of 12" x 12" was fabricated in accordance with Swedlow drawing 77050. As originally built, water cooling capability was not provided. Results of the first two moldings indicated a slight decrease of haze with rapid mold cooling. Therefore, the 12" x 12" mold was redesigned and modified to provide for water cooling. Subsequent moldings demonstrated that rapid cooling of the mold was not necessary to obtain clear moldings.

Preliminary molding trials were conducted using the cycle furnished by AMMRC. The cycle furnished was:

Temperature:	+325°F
Pressure:	2000 PSI
Time:	10 minutes dwell

The following procedure was established for initial moldings in Task I.

- The film was laid-up, oversize, by cross-plying successive layers of film and then trimmed to the 12" x 12" molding size with a power paper cutter.
- The cross-plied package was dried, under vacuum, for 6 hours at +220°F.
- Pressure was applied prior to heating and was maintained throughout the cycle until the molded sheet had cooled to approximately +130°F.

The initial moldings were not transparent. Several additional molding trials were conducted, varying the molding and drying conditions. All resulted in moldings of low light transmission.

At this point it was determined that there was no noticeable difference in the moldings as a result of the film drying temperature. Therefore, drying the film at room temperature, under vacuum, became the standard.

At the direction of the Technical Supervisor, moldings of N600 film, roll oriented by Revere, were made. These moldings also exhibited low light transmission. In addition, cross-plied samples of N400, roll oriented by American Can, were supplied to AMMRC for evaluation. Since the moldings produced by AMMRC from these cross-plied samples also had low light transmission, it was concluded that the N400 film, roll oriented by American Can, was at fault and not the Swedlow processing. Samples of films and laminates were submitted by the Technical Supervisor to Hercules for examination. IR analysis showed that the clear laminate made in the initial work and believed to be N400 homopolymer was actually N600 homopolymer (N400 designates copolymer film). This mixup led to the mistaken designation of N400 as the reference film instead of N600. Also, the 3 and 10 mil films labeled N600, rolled by Revere, and used in molding trials number 10, 12, 25, 26 and 27 were actually N400. (The N600 films rolled by American Co. were corectly labeled.) Aithough the film designated N400II rolled by Revere was not examined, it is suspected that this is actually N600.

Also at the direction of the technical supervisor, samples of B-503, a biaxially oriented film, were tried. This film resulted in clear moldings of high light transmission.

Molding trials Number 15 and 16 were submitted to AMMRC for establishment of the reference material ballistic limit. These moldings were produced from N400 film, roll oriented by American Can.

The V_{50} limit for the molded N400 reference material was 1221 ft./sec. for Number 15 and 1238 ft./sec. for Number 16. The ballistics tests were conducted by AMMRC using caliber .22, 17 grain fragment simulating projectiles (MIL-P-46593) per MIL-STD-662A except for the averaging of 6 rounds instead of 10 within a spread of 125 ft/sec. for the V_{50} ballistics limit velocity.

The moldings produced in Task I were Numbers 1 through 16. A summary of the Task I molding trials is contained in Appendix A. The actual molding cycles are contained in Appendix B as Figures I-1 through I-5. The light transmission of the N400 moldings ranged from a low of 12% to a high of 56%. Appendix C contains the individual light transmission and haze readings obtained on Molding Number 14.

Task II - Effect of Film Characteristics

The objectives of this task were to (1) evaluate additional films and compare them with the reference film, N400, from Task I; and (2) select the one film for optimization, that was found to possess, overall, the qualitites required to produce transparent polyolefin armor with the desired performance level.

A total of 23 additional films were received. Eleven films were originally received and are shown in Table 3.

TABLE 3

TASK II FILMS

Film	Manufacturer	Rolled By
N-600	Hercules	American Can
N-600 (1)	Hercules	Revere
AT-61	Crown Zellerbach	American Can
B-503	Hercules	(2)
P-2102	Toyoba	(2)
P-81B	Mobil	(2)
N-400-II (3)	Hercules	Revere
Capacitor	General Electric	(2)
X-207	Cryovac	(2)
B-500	Hercules	(2)
SK-300-2	Trea	(2)

(1) Film identified as N600, is N400

(2) Biaxially oriented film

(3) Film suspected to be N600.

An additional 12 films, shown in Table 4, were received later in the program.

TABLE 4

TASK II FILMS

Film	Manufacturer	Rolled By
EK-500	Hercules	(1)
NB81-59-99-1	Diamond Shamrock	Archer
NB81-59-99-2	Diamond Shamrock	Archer (2)
NB81-59-99-2	Diamond Shamrock	Archer(3)
NB81-59-99-3	Diamond Shamrock	Archer(4)
NB81-59-99-3	Diamond Shamrock	Archer(5)
NB81-59-99-4	Diamond Shamrock	Archer
NB81-59-99-5	Diamond Shamrock	Archer
PP-41-6300-4153	El Rexene	Archer
Dart Ind.	El Rexene	Archer
4230-E	Eastman Tenite	Archer
AT-40	Crown Zellerbach	Archer

(1) Biaxially oriented film
(2) 10:1 Orientation
(3) 12:1 Orientation
(4) 8:1 Orientation
(5) 6:1 Orientation

Properties for all 23 films received in Task II are shown in Table 5.

TABLE 5

RESULTS OF FILMS RECEIVED IN TASK II

Film	Type	Orientation	Light Transmission (%)	Haze (%)	Thickness (Inches)
N600 (1)	Homopolymer	4:1	91.9	1.2	0.0015
N600 (2)	Homopolymer	3:1	92.2	3.7	0.0025
AT-61	Homopolymer	4:1	92.3	3.5	0.001
B-503	Homopolymer	(3)	92.4	1.3	0.001
P-2102	Homopolymer	(3)	92.0	3.0	0.002
P-81B	Homopolymer	(3)	92.9	4.0	0.002
N400II (4)	Copolymer	3:1	93.1	4.8	0.001
Capacitor	Homopolymer	(3)	93.3	5.4	0.001
X-207	Homopolymer	(3)	92.8	1.7	0.001
B-500	Homopolymer	(3)	92.8	1.4	0.002
SK-300-2	Copolymer	(3)	92.4	3.5	0.003
EK-500	Homopolymer	(3)	92.2	1.3	0.001/0.0012
NB81-59-99-1	Homopolymer	10:1	92.9	15.0	0.0025/0.0027
NB81-59-99-2	Homopolymer	10:1	91.3	9.7	0.0025
NB81-59-99-2	Homopolymer	12:1	92.8	11.0	0.0025
NB81-59-99-3	Copolymer	8:1	92.5	6.0	0.0035
NB81-59-99-3	Copolymer	6:1	92.7	9.5	0.0032
NB81-59-99-4	Copolymer	8:1	92.5	6.5	0.002
NB81-59-99-5	Copolymer (5)	8:1	92.2	7.2	0.0028
PP-41-6300-4153	Homopolymer	10:1	92.6	10.6	0.002/0.0028
Dart Ind.	Homopolymer	8:1	91.2	22.0	0.0035
4230-E	Homopolymer	10:1	90.2	12.2	0.002
AT-40	Copolymer	6:1	92.3	4.6	0.0012

(1) Oriented by American Can

(2) Film identified as N600 Homopolymer, oriented by Revere, is N400 Copolymer

(3) Biaxially oriented

(4) Film suspected to be N600 Homopolymer

(5) U. V. Stabilizer

Of these 12 additional films, 3 were to be selected to complete a total of 14 films for Task II evaluation. The 12 films were evaluated to determine which 3 should be included in Task II. The method used to rate the films, and the results obtained, are contained in Table 6.

TABLE 6

FILM RATING(1)

Film	Luminous Transmission WT = 10	Haze WT = 9	Film Condition WT = 7	Film Caliper WT = 5	Roll Condition WT = 4	Degree of Orient. WT = 3	Total Weighted Score
	Score / Wt x Sc	Score / Wt x Sc	Score / Wt x Sc	Score / Wt x Sc	Score / Wt x Sc	Score / Wt x Sc	
Hercules EK 500	6 / 60	17 / 108	12 / 84	5 / 25	4 / 16	8 / 24	317
Dia. Sham. -1, 10:1	12 / 120	2 / 18	7 / 49	9 / 45	3 / 12	11 / 33	277
Dia. Sham. -2, 10:1	11 / 110	6 / 54	3 / 21	8 / 40	5 / 20	11 / 33	278
Dia. Sham. -2, 12:1	5 / 50	4 / 36	2 / 14	8 / 40	0 / No Roll	12 / 36	176
Dia. Sham -3, 8:1	10 / 100	10 / 90	10 / 70	12 / 60	3 / 12	10 / 30	362
Dia. Sham -3, 6:1	8 / 80	7 / 63	6 / 42	11 / 55	4 / 16	9 / 27	283
Dia. Sham -4, 8:1	8 / 80	9 / 81	8 / 56	7 / 35	2 / 8	10 / 30	290
Dia. Sham -5, 8:1 (UV)	6 / 60	8 / 72	11 / 77	10 / 50	1 / 4	10 / 30	293
El Rexene -4153, 10:1	9 / 90	5 / 45	5 / 35	10 / 50	5 / 20	11 / 33	273
El Rexene (Dart), 8:1	4 / 40	1 / 9	9 / 63	12 / 60	3 / 12	10 / 30	214
Eastman 4230-E, 10:1	3 / 30	3 / 27	4 / 28	7 / 35	4 / 16	11 / 33	169
Crown Zell. AT 40, 6:1	7 / 70	11 / 99	1 / 7	6 / 30	3 / 12	9 / 27	245

(1) LOGIC: Weight — Highest value given to properties regarded as most important to produce a good laminate (clarity, Min. Haze, etc.)

Score — Applied as follows.

(1) Lum. Trans. highest rec'd highest score, (2) Haze Lowest rec'd highest score, (3) film and roll condition Subjective judgement Best appearance, highest score (4) film caliper - Thickest film highest score. (5) Orientation Greatest orientation, highest score

NOTE — Ties or similar values received same score.

The three films selected were the Diamond Shamrock NB81-59-99-3 with 8:1 orientation, the Hercules EK-500 and the El Rexene PP-41-6300-4153.

In addition to the properties reported in Table 5, Orientation Release Stress was determined on the fourteen Task II films, plus the N400 Task I reference film. The results of this testing is summarized in Table 7 for the fifteen films. The

Orientation Release Stress testing was conducted by an independent test laboratory and copies of the test reports are contained in Appendix D.

TABLE 7

RESULTS OF ORIENTATION RELEASE STRESS TESTING

Film	Maximum Temperature Attained (°F)	Orientation Release Stress, Direction: Machine (Psi)	Orientation Release Stress, Direction: Transverse (Psi)
N-400	250	838	Nil
N-600 (Am.Can)	275	435	Nil
N-600 (Rev.) (1)	250	529	Nil
AT-61	250	552	Nil
B-503	325	289	205
P-2102	318	131	151
P-81B	332	174	330
N-400 II (2)	262	469	21.8
Capacitor	328	[illegible]	324
X-207	334	[illegible]	499
B-500	335	288	298
SK-300-2	328	486	51.4
EK 500	335	254	290
NB81-59-99-3	276	656	1.2
PP-41-6300-4153	305	615	1.2

(1) Film identified as N600, is N400.
(2) Film suspected to be N600.

Moldings, 12 inches by 12 inches by 20 ounces/foot^2, were prepared of each of the 14 Task II films. A total of 57 molding trials were made in Task II (Number 17 through 73).

The moldings were evaluated for light transmission, haze and ballistics. The ballistics testing, to determine the V_{50} limit, was conducted by AMMRC as described in Task I.

The average results obtained are shown in Table 8. N-400, the Task I reference film, is included for comparative purposes.

TABLE 8

RESULTS OF FILM MOLDINGS IN TASK II

		MOLDED PANEL PROPERTIES		
FILM	MANUFACTURER	LIGHT TRANSMISSION (%)	HAZE (%)	V_{50} (FPS)
N-400	HERCULES	12.0-56.0	34.0-46.0	1221-1238
N-600(1)	HERCULES	17.0-62.0	74.0-100.0	1074
N-600(2)	HERCULES	87.0-91.0	1.0-8.0	995
AT-61	CROWN ZELLERBACH	64.0-75.0	34.0-46.0	928
B-503	HERCULES	76.0-83.0	3.0-8.0	1035
P-2102	TOYOBA	78.0-83.0	23.0-27.0	
P-818	MOBIL	72.0-74.0	7.0-11.0	
N-400 II(3)	HERCULES	84.0-88.0	11.0-28.0	975-1025
CAPACITOR	GENERAL ELECTRIC	79.0-82.0	4.0-9.0	
X-207	CRYOVAC	76.0-85.0	5.0-8.0	
B-500	HERCULES	82.0-84.0	3.0-5.0	
SK-300-2	TREA	37.0-88.0	5.0-100.0	1234
EK-500	HERCULES	87.0-90.0	1.0-4.0	
NB81-59-99-3	DIAMOND SHAMROCK	10.0-43.0	35.0-74.0	975-1025
PP-41-6300-4153	EL RE INE	55.0-92.0	11.0-44.0	

(1) Film identified as N600, rolled by Revere, is N4

(2) Rolled by American Can

(3) Film suspected to be N600

A summary of the Task II molding trials, Numbers 17 through 73, is contained in Appendix A. The actual molding cycles are contained in Appendix B as Figures II-1 through II-20.

The individual light transmission and haze readings obtained on moldings produced in Task II, Numbers 17 through 73, are contained in Appendix C.

The results of the moldings produced in Task II were reviewed with AMMRC and Hercules EK-500, a commercially available biaxially oriented homopolymer polyolefin film, was the material selected for optimization.

As can be seen from Table 8, 12 inch by 12 inch by 20 ounces/foot^2 moldings produced from the Hercules EK-500 film possessed the following properties.

Light Transmission	> 87%
Haze	<4.0%
Ballistic Resistance V_{50}	975 - 1025 feet/second (F.P.S.)

Typical properties of the Hercules EK-500 film are shown in Table 9.

TABLE 9

TYPICAL PROPERTIES HERCULES EK-500 FILM

PROPERTY	VALUE
SPECIFIC GRAVITY	0.902
TENSILE STRENGTH, PSI	30,000 MACHINE AND TRANSVERSE DIRECTIONS
TENSILE MODULUS, PSI	350,000 MACHINE AND TRANSVERSE DIRECTIONS
ELONGATION, %	70-100
LIGHT TRANSMISSION, %	92.0
HAZE, %	2.0
WATER ABSORPTION, %	< 0.005
THICKNESS, INCHES	0.001

Task III - Molding Flat Sheet

The objective of this task was the optimization of the molding parameters to convert the oriented EK-500 film into fragment resistant transparent armor.

Sufficient EK-500 film was purchased to complete the contract. The light transmission, haze and orientation release stress was determined on the purchased film. The results obtained are shown in Table 10. The orientation release stress testing was conducted by an independent test laboratory and a copy of the test report is contained in Appendix D.

TABLE 10

EK-500 FILM PROPERTIES

Property	Result
Average Light Transmission (%)	93.7
Average Haze (%)	2.2
Orientation Release Stress	
o Maximum Temperature Attained (°F)	324
o Average PSI, Machine Direction	214
o Average PSI, Transverse Direction	156

Prior to the process optimization, a study was conducted to determine if cross-plying of the EK-500 was necessary, since the EK500 film is biaxially oriented. As previously discussed, cross-plying of the uniaxially oriented polyolefin film, (~4.5:1), was found to be necessary to take advantage of the increased tensile strength produced by the orientation.

Six moldings, (Trial Numbers 74 through 79), 12 inches by 12 inches by 20 ounces/foot^2, of cross-plied and non-cross-plied EK-500 film were produced and the ballistic limits determined by AMMRC. It was concluded that there was no noticeable difference between the cross-plied and non-cross-plied EK-500 film. Therefore, cross-plying of the EK-500 film was not required.

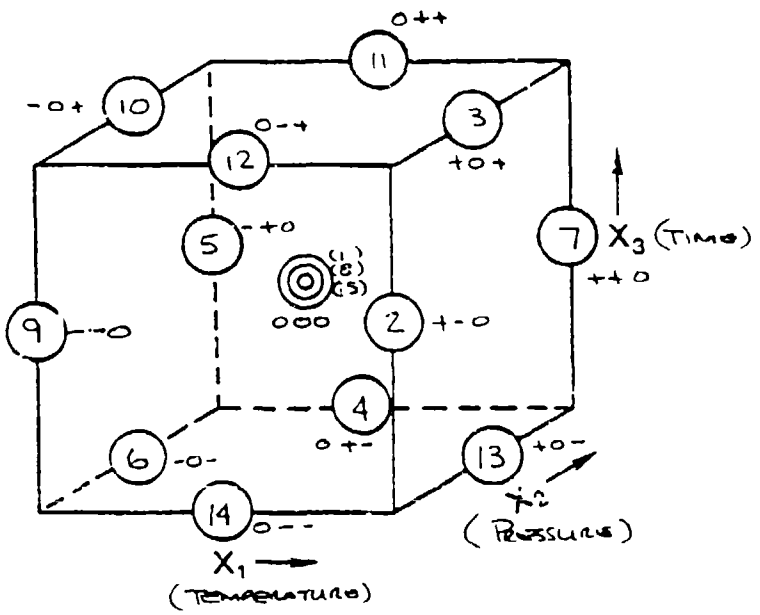
To optimize the molding parameters for the EK-500 film, an experimental plan was prepared utilizing the Box-Behnken method for variables (Reference 8).

The Box-Behnken design for the variables consists of twelve edge points all lying on a single sphere about the center of the experimental region, plus three replicates of the center point. The Box-Behnken experimental plan establishes the parameters considered optimum.

The range of parameters evaluated to optimize the molding process are as follows:

Temperature:	300°F, 330°F, 360°F
Pressure:	100 psi, 1550 psi, 3000 psi
Time:	1 minute, 30 minutes, 60 minutes

Included as Figure 1, is the Box-Behnken design which depicts the parameters established to determine the optimum processing cycling.



ITEM	UNITS	LOW (-)	MID (0)	HIGH (+)
TEMPERATURE	°C	300	330	360
PRESSURE	PSI	100	1550	3000
TIME	MINUTES	1	30	60

FIGURE 1

BOX-BEHNKEN DIAGRAM
PARAMETERS ESTABLISHED TO
DETERMINE OPTIMUM PROCESSING CYCLE

Included in Appendix E, is a copy of Swedlw, Inc. Engineerinng Report No. 948 "Test Procedure for Determining the Optimum Processing Condition for Transparent Polyolefin Film Armor".

A total of 20 moldings, (Trial Numbers 80 through 99), 12 inches by 12 inches by 20 ounces/foot^2, were prepared in accordance with Report No. 948. Of these, 16 were submitted to AMMRC for determination of the V_{50} limit.

The results of the light transmission and haze of all 20 moldings, as well as the V_{50} limit of the 16 moldings, are shown in Table 11. In addition, the conditions used for each of the 20 moldings is included.

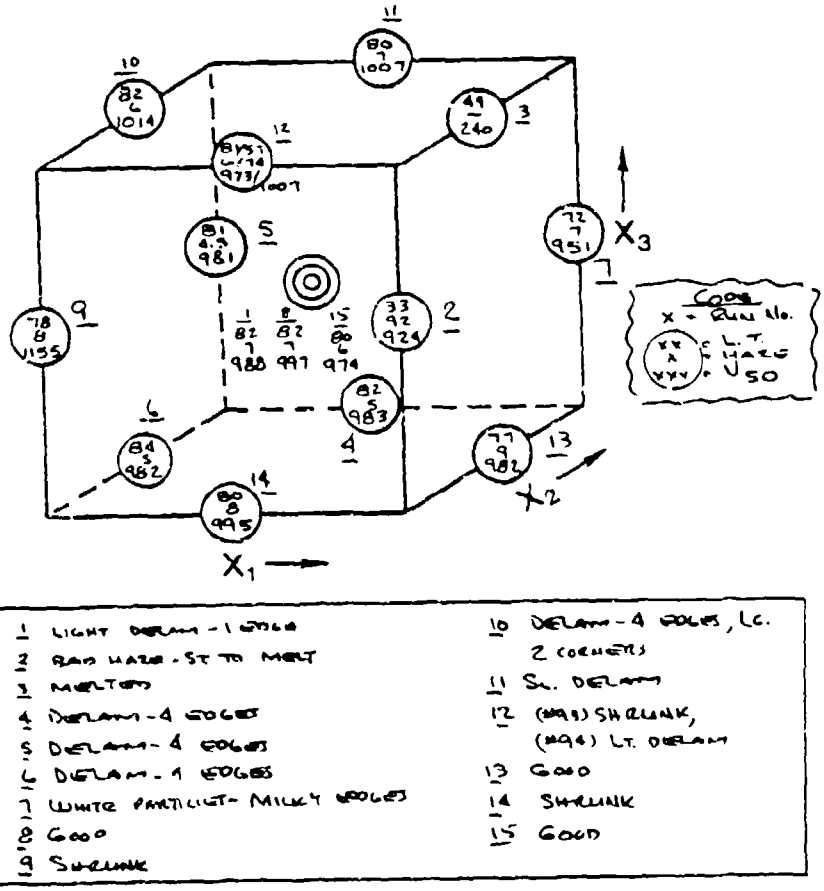
Figure 2 is the Box-Behnken design which depicts the results obtained on the parameters established, (light transmission, haze and ballistic limit).

TABLE 11

RESULTS OF PROCESS OPTIMIZATION

Trial Number	Run (1) Number	Temperature (°F)	Time (Minutes)	Pressure (PSI)	Light Trans. (%)	Haze (%)	V_{50} (FPS)
80	6	300	1	1550	84.3/86.2	3.1/5.1	982
81	1	330	30	1550	81.9/84.8	2.3/5.2	(3)
82	3	360 (2)	60	1550	49.7/58.4	-	240
83	10	300	60	1550	82.6/84.4	2.8/5.6	1014
84	8	330	30	1550	82.3/84.4	3.3/6.7	997
85	15	330	30	1550	80.0/81.3	3.0/6.4	974
86	9	300	30	100	78.5/79.3	6.4/7.7	1155
87	1	330	30	1550	83.6/86.3	2.6/7.0	(3)
88	1	330	30	1550	82.3/85.0	2.7/7.3	988
89	13	350	1	1550	77.3/82.1	5.2/8.5	982
90	2	350	30	500	33.0/72.6	6.5/92.8	924
91	14	330	1	500	80.6/83.3	2.8/8.0	995
92	12	330	60	500	Not Measured		(3)
93	12	330	60	500	54.7/79.0	8.7/74.8	1007
94	12	330	60	750	81.8/84.5	3.3/6.0	973
95	5	300	30	3000	81.6/83.2	2.9/4.5	981
96	4	300	1	3000	82.4/84.3	2.4/4.6	983
97	11	330	60	3000	80.1/82.5	2.8/7.0	1007
98	7	350	30	3000	55.5/65.2	51.7/88.6	(3)
99	7	350	30	3000	72.3/75.3	6.4/7.3	951

(1) Run number as established by experimental Plan Report No. 948
(2) Melted at 352°F.
(3) Not tested for V_{50}



1 LIGHT DELAM - 1 EDGE	10 DELAM - 4 EDGES, LC. 2 CORNERS
2 BAD HAZE - ST TO MELT	11 SL. DELAM
3 MELTED	12 (#99) SHRUNK, (#94) LT. DELAM
4 DELAM - 4 EDGES	13 GOOD
5 DELAM - 4 EDGES	14 SHRUNK
6 DELAM - 4 EDGES	15 GOOD
7 WHITE PARTICLES - MILKY EDGES	
8 GOOD	
9 SHRUNK	

FIGURE 2

BOX-BEHNKEN DIAGRAM
RESULTS OF PROCESSING VARIABLES

Of the 4 moldings not ballistically tested, three were evaluated for preliminary resistance to debonding in accordance with ASTM D-756 procedure E(-57°C low temperature). The edges of the moldings were machined to remove edge delaminations. The moldings were measured prior to each cycle and were observed for debonding at the completion of each cycle. The detailed results are contained in Table 12.

TABLE 12

RESULTS OF RSISTANCE TO DEBONDING

TESTING PER ASTM D-756, PROCEDURE E(-57°C)

PANEL NO. 81 (330°F, 1550 PSI, 30 MIN.)

Condition	Weight (Gms)	Width (Ins)	Length (Ins)	Thickness (In.) Ctr.	1	2	3	4
Original	473.7	10.83	10.75	.278	.269	.275	.275	.265
First Cycle	474.1	10.73	10.69	.281	.267	.278	.279	.270
Second Cycle	474.0	10.73	10.69	.282	.268	.278	.279	.271
Third Cycle	474.1	10.72	10.67	.283	.269	.278	.281	.270
Fourth Cycle	473.8	10.59	10.56	.288	.275	.284	.287	.275
Fifth Cycle	473.9	10.61	10.56	.288	.274	.284	.287	.276

NOTE: Very slight edge debonding after the fifth cycle.

PANEL NO. 99 (330°F, 3000 PSI, 30 MIN.)

Condition	Weight (Gms)	Width (Ins)	Length (ins)	Thickness (Ins.) Ctr	1	2	3	4
Original	503.4	10.95	11.91	.263	.261	.252	.243	.254
First Cycle	503.5	10.91	11.83	.274	.263	.254	.245	.255
Second Cycle	503.5	10.89	11.88	.274	.264	.255	.246	.256
Third Cycle	503.4	10.89	11.86	.264	.263	.254	.245	.257
Fourth Cycle	503.4	10.86	11.81	.266	.264	.256	.248	.259
Fifth Cycle	503.3	10.86	11.83	.265	.264	.256	.249	.259

NOTE: Edge delamination and warpage after first cycle

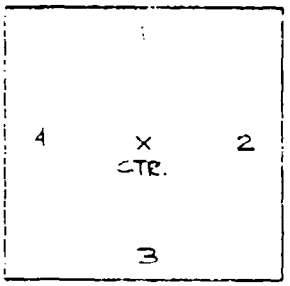
TABLE 12 (CONT'D)

PANEL NO. 92 (330°F, 500 PSI, 60 MIN.)

Condition	Weight (Gms)	Width (Ins)	Length (Ins)	Thickness (Ins.) Ctr	1	2	3	4
Original	517.1	10.69	11.80	.276	.275	.277	.267	.267
First Cycle	516.4	10.64	11.72	.278	.278	.278	.268	.269
Second Cycle	516.4	10.64	11.70	.279	.278	.279	.270	.270
Third Cycle	516.3	10.64	11.69	.278	.277	.278	.269	.271
Fourth Cycle	516.2	10.53	11.56	.292	.289	.286	.276	.285
Fifth Cycle	516.4	10.53	11.55	.291	.289	.287	.278	.284

NOTE: Edge delamination and warpage after first cycle

Location of thickness readings (all panels)



Based on the light transmission, haze and ballistic limit results contained in Figure 2 and Table 11, the preliminary resistance to debonding contained in Table 12 and moldings of EK-500 produced in Task II, the following was selected as the optimum cycle.

Temperature:	+330°F
Pressure:	2000 psi
Time:	30 Minutes

A typical molding cycle, time versus temperature, is illustrated in Figure 3.

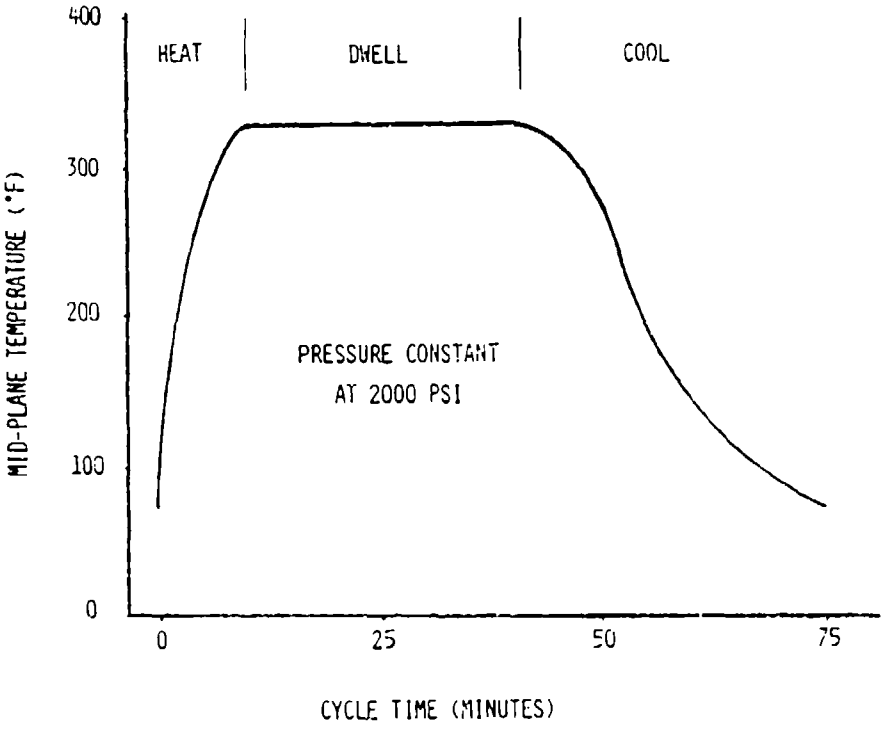


FIGURE 3

TYPICAL MOLDING CYCLE

An additional 21 moldings, Trial Numbers 100 through 120, 12 inches by 12 inches by 20 ounces/foot^2, were prepared using the processing cycle selected as the optimum. These moldings were utilized for testing to the requirements established for molded polyolefin film armor (Table 1 of Task I). Some of the moldings, (#107, 108, 109, 110, 113 and 114), exhibited high haze, originally thought to be due to excessive moisture. However, it was subsequently determined, in Task IV, to have been caused by localized hot spots in the molding tool.

The following tests were conducted by Swedlow, Inc. on the moldings prepared in Task III using the optimum processing cycle.

- Light transmission and haze
- Thickness

- o Deviation of line of sight
- o Interlaminar shear strength
- o Bond tensile strength
- o Resistance to debonding

Additional moldings were prepared using the optimum processing cycle and submitted to AMMRC for ballistics testing.

The results of the Swedlow testing is as follows:

- o Light Transmission and Haze

  Test procedure: ASTM D-1003

  The minimum to maximum range of light transmission and haze for trial numbers 100 through 120 are contained in Table 13.

TABLE 13

LIGHT TRANSMISSION AND HAZE

TESTING AT +75°F PER ASTM D-1003

Trial Number	Light Trans (%)	Haze (%)	Trial Number	Light Trans (%)	Haze (%)
100	72.3/83.3	2.5/9.1	111	77.5/84.7	3.4/5.9
101	74.3/83.4	3.7/6.7	112	79.7/84.4	1.6/4.9
102	79.5/84.9	3.5/6.8	113	72.2/85.1	4.1/63.9
103	80.1/84.5	2.1/4.6	114	75.8/84.9	2.9/56.6
104	78.6/82.9	3.0/5.0	115	81.4/86.9	0.9/3.8
105	78.5/83.3	2.4/5.7	116	82.1/86.0	2.2/4.6
106	77.8/82.7	3.2/5.7	117	82.3/84.6	1.3/4.5
107	81.1/85.0	3.0/11.9	118	82.7/85.9	2.5/6.7
108	79.3/86.2	4.0/25.7	119	81.6/85.0	2.6/4.9
109	81.3/86.7	2.6/12.9	120	81.7/84.8	2.3/4.8
110	62.7/82.7	4.3/91.3			

o Thickness

Test Procedure: ASTM D-374

Trial Numbers 105, 116, 118 and 120 were selected for determination of thickness.

Table 14 contains the results obtained.

TABLE 14

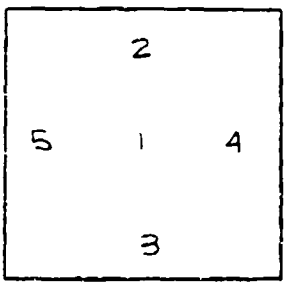
THICKNESS

TESTED AT +75°F, PER ASTM D-374

PANEL NUMBER	THICKNESS (INCHES) 1	2	3	4	5	AVERAGE THICKNESS (INCHES)
105	.280	.265	.271	.291	.248	.271
116	.281	.247	.291	.276	.261	.271
118	.275	.276	.261	.279	.252	.269
120	.279	.256	.281	.274	.258	.270

PANEL NUMBER	THICKNESS VARIATION (INCHES)	(%)
105	+.020,-.023	+7.4,-8.5
116	+.020,-.024	+7.4,-8.9
118	+.010,-.017	+3.7,-6.3
120	+.011,-.014	+4.1,-5.2

LOCATION OF THICKNESS READINGS (ALL PANELS)



o Deviation of Line of Sight

Test Procedure: ASTM D-881-48.

Trial Numbers 105, 116, 118 and 120 were also selected for determination of deviation of line of sight.

Table 15 contains the results obtained.

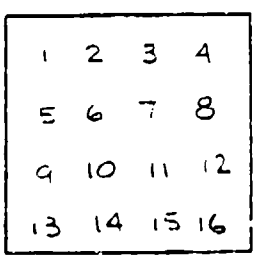
TABLE 15

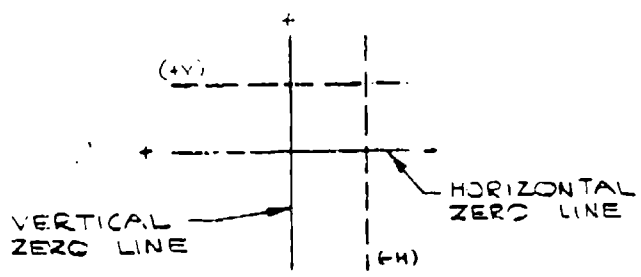
MAXIMUM DEVIATION OF LINE OF SIGHT TESTED PER ASTM D-881-48

PANEL NUMBER	HORIZONTAL/ VERTICAL[1]	ANGULAR DEVIATION (MINUTES) PER LOCATION															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
105	H	-9	-10	-7	-6	-11	-9	-7	-5	-13	-8	-6	-5	-10	-8	-7	-5
	V	-5	-5	-5	-3	-4	-5	-5	-3	-1	0	0	0	+5	+5	+4	+3
105 (Rotated 90°)	H	+5	+7	+5	+4	+3	+4	+3	+2	+1	0	-1	-1	-3	-3	-3	-2
	V	-8	-9	-6	-2	-10	-10	-6	-5	-10	-10	-5	-5	-10	-10	-6	-5
116	H	-6	-4	+1	+3	+7	-3	+2	+6	-6	-4	+1	+5	-5	-3	+2	+3
	V	-10	-10	-11	-11	-10	-11	-10	-8	-6	-5	-7	-8	-1	-5	-6	-5
116 (Rotated 90°)	H	+10	+11	+15	+13	+6	+11	+10	+9	+5	+4	+3	+7	+6	+1	+4	+5
	V	-6	-5	-1	-2	-7	-6	0	+3	-6	-6	-1	+2	-5	-5	-1	+2
118	H	-9	-6	-4	-2	-10	-7	-4	-1	-10	-6	-2	-1	-10	-7	-3	-3
	V	0	-2	-2	0	-2	-3	-2	-1	+2	+1	0	+4	+5	-5	+5	+8
118 (Rotated 90°)	H	0	0	0	+4	-1	+3	+2	+1	-2	-2	0	-1	-7	-5	-5	-4
	V	-8	-7	-4	-2	-10	-7	-4	-1	-10	-7	-3	0	-8	-7	-4	-2
120	H	-7	-4	+1	+1	-10	-6	0	+1	-7	-2	+1	+1	-5	-1	+1	0
	V	-7	-9	-8	-11	-6	-8	-8	-7	-5	-1	-4	-4	-4	-2	-2	-1
120 (Rotated 90°)	H	+7	+8	+11	+10	+4	+5	+5	+6	+2	+5	+3	+3	+3	+2	+2	+1
	V	-7	-5	0	+1	-8	-7	0	+2	-8	-6	0	+2	-7	-5	0	0

Notes: (1) HORIZONTAL - Readings left or right of the vertical zero line, intersecting the horizontal zero line.
VERTICAL - Readings above or below the horizontal zero line, intersecting the vertical zero line.

LOCATION OF READINGS (ALL PANELS)

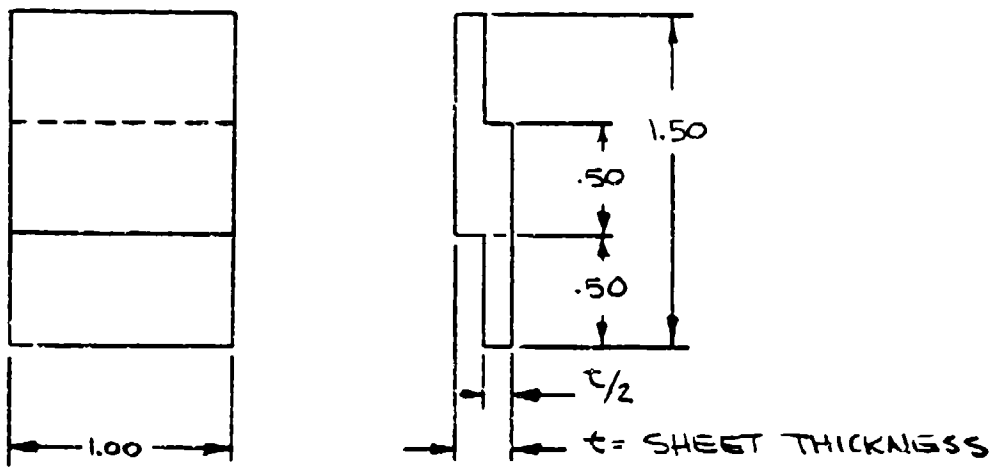




o Interlaminar Shear Strength

Test Procedure: Military Specification MIL-P-25690, Paragraph 4.6.9

The specimen configuration used for determination of interlaminar shear strength is shown in Figure 4.



TEST SPECIMEN CONFIGURATION
INTERLAMINAR SHEAR STRENGTH

FIGURE 4

Trial Numbers 101, 111, and 114 were selected for interlaminar shear strength testing. Trial Number 114 was included in this determination because of the presence of high haze.

Table 16 contains the results obtained.

TABLE 16

INTERLAMINAR SHEAR STRENGTH

TESTING AT +75°F PER MILITARY SPECIFICATION MIL-P-25690, PARAGRAPH 4.6.9

PANEL NUMBER	SPECIMEN NUMBER		INTERLAMINAR SHEAR STRENGTH (PSI)
101	1		1751
	2		1713
	3		1781
	4		1367
	5		1685
		Average:	1659
111	1		1689
	2		1456
	3		1572
	4		1517
	5		1795
		Average:	1606
114	1		980
	2		947
	3		1168
	4		838
	5		1024
		Average:	951

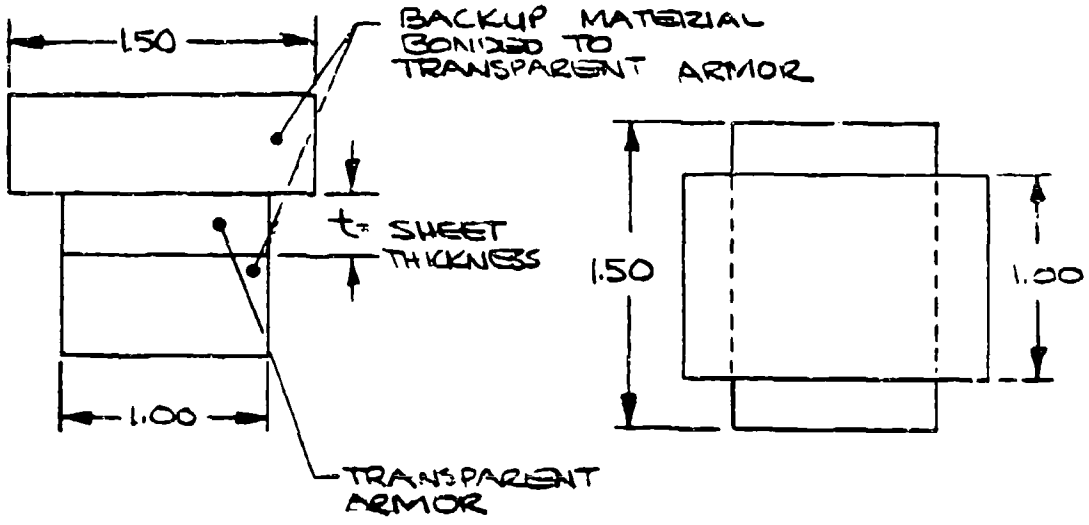
Although the high haze panel, (No. 114), had approximately forty percent less interlaminar shear strength than the panels without high haze, (No. 101 and 111), the average of 951 PSI was very close to the original target value of 1000 PSI as specified in our proposal 75-0301, paragraph 2.4.

The panels without the high haze had average interlaminar shear strengths of 1606 and 1659 PSI, well above the original target value of 1000 PSI.

- o Bond Tensile Strength

  In addition to the interlaminar shear strength, bond tensile strength was also determined on molding trial numbers 101, 111, and 114.

The specimen configuration used for determination of bond tensile strength is shown in Figure 5. Backup material was bonded to the molded polyolefin test specimens to accommodate the test fixture.



TEST SPECIMEN CONFIGURATION
BOND TENSILE STRENGTH

FIGURE 5

Testing was accomplished at +75°F at a loading rate of 200 pounds/minute.

Table 17 contains the results obtained.

TABLE 17

BOND TENSILE STRENGTH

TESTING AT +75°F

PANEL NUMBER	SPECIMEN NUMBER	BOND TENSILE STRENGTH (PSI)	TYPE FAILURE
101	1	137	Failure of adhesive to backup
	2	148	
	3	150	
	4	170	
	5	169	
	Average:	155	
111	1	141	Failure of adhesive to backup
	2	169	
	3	158	
	4	166	
	5	133	
	Average:	153	
114	1	49	Cohesive failure of lamination
	2	44	
	3	51	
	4	40	
	5	55	
	Average:	48	

The bond tensile strength exhibited similar results to the interlaminar shear strength. The high haze panel had approximately seventy percent less bond tensile strength than the panels without high haze.

- Resistance to Debonding

Test Procedure: ASTM D-756, Procedure E (-57°C)

Trial numbers 102, 106, and 115 were selected for resistance to debonding.

Very slight edge delamination was observed after the first cycle on two of the three panels. The third panel did not exhibit any delamination. There was no change to any of the panels at the completion of the five cycles.

The detailed results of the debonding testing are contained in Table 18. Table 19 contains the luminous transmittance and haze of the three panels after completion of the resistance to debonding tests.

TABLE 18

RESULTS OF RESISTANCE TO DEBONDING

TESTING PER ASTM D-756, PROCEDURE E(-57°C)

PANEL NO. 102

Condition	Weight (GMS)	Width (INS)	Length (INS)	Thickness (INS) Ctr.	1	2	3	4
Original	570.3	11.89	11.92	.276	.242	.257	.286	.273
First Cycle	570.1	11.80	11.86	.279	.246	.262	.290	.278
Second Cycle	569.3	11.83	11.84	.278	.246	.262	.290	.278
Third Cycle	570.1	11.83	11.86	.278	.246	.262	.289	.279
Fourth Cycle	571.5	11.86	11.86	.278	.246	.262	.290	.279
Fifth Cycle	570.2	11.83	11.86	.276	.247	.262	.290	.278

PANEL NO. 106

Condition	Weight (GMS)	Width (INS)	Length (INS)	Thickness (INS) Ctr.	1	2	3	4
Original	567.2	11.89	11.91	.275	.244	.259	.287	.267
First Cycle	567.1	11.81	11.84	.277	.246	.261	.292	.269
Second Cycle	566.9	11.81	11.83	.278	.246	.261	.292	.270
Third Cycle	567.2	11.81	11.83	.277	.246	.262	.292	.269
Fourth Cycle	567.7	11.81	11.83	.276	.246	.261	.292	.269
Fifth Cycle	567.3	11.81	11.84	.277	.246	.261	.292	.270

NOTE: VERY SLIGHT EDGE DELAMINATION AFTER FIRST CYCLE

TABLE 18 (CONT'D)

PANEL NO. 115

Condition	Weight (GMS)	Width (INS)	Length (INS)	Thickness (INS) Ctr.	1	2	3	4
Original	570.1	11.89	11.89	.278	.241	.253	.287	.274
First Cycle	570.1	11.83	11.89	.280	.246	.257	.291	.278
Second Cycle	569.7	11.83	11.89	.280	.246	.257	.290	.278
Third Cycle	570.4	11.81	11.88	.280	.246	.257	.291	.278
Fourth Cycle	568.8	11.81	11.89	.280	.246	.256	.291	.278
Fifth Cycle	570.0	11.81	11.89	.280	.246	.257	.291	.278

NOTE: VERY SLIGHT EDGE DELAMINATION AFTER FIRST CYCLE

LOCATION OF THICKNESS READINGS
(ALL PANELS)

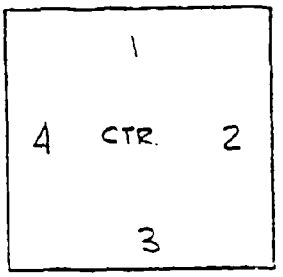


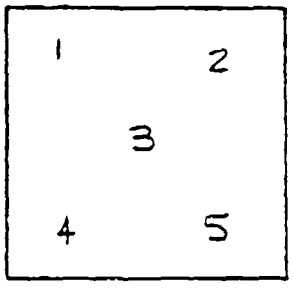
TABLE 19

LIGHT TRANSMISSION AND HAZE

AFTER RESISTANCE TO DEBONDING

TESTING AT +75°F PER ASTM D-1003

Panel Number		LOCATION OF READING 1	2	3	4	5
102	LT =	79.6	80.1	78.3	78.5	79.4
	H =	3.6	3.0	3.7	3.9	3.2
106	LT =	80.7	80.5	79.1	79.2	79.2
	H =	3.9	4.0	4.6	3.9	4.0
115	LT =	83.2	82.8	81.3	81.5	81.5
	H =	2.9	2.9	3.8	3.0	2.8



Location of light transmission and haze readings

The molded polyolefin armor experienced a light transmission loss of 0.2 to 2.5% and an increase of haze of 0.5 to 1.4%, as a result of the debonding testing.

Previous studies have shown that interlaminar adhesion sufficient to resist debonding is required, but complete fusion into a homogenous mass is undesirable. Resolution of these apparently conflicting requirements was accomplished under Task III efforts.

A summary of the Task III molding trials, Numbers 74 through 120, is contained in Appendix A.

The actual molding cycles are contained in Appendix B as Figures III-1 through III-34.

The individual light transmission and haze readings obtained on each of the moldings, trial numbers 74 through 120, are contained in Appendix C.

Attached as Table 20 are the results obtained on Task III moldings, and are compared to the original program objectives.

TABLE 20

RESULTS OF EK-500 PANELS MOLDED

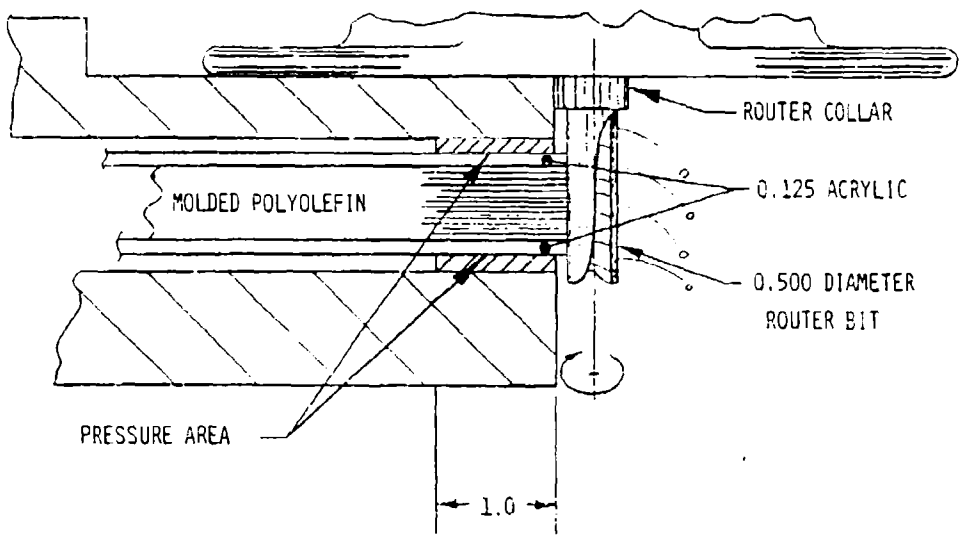
USING OPTIMUM CONDITIONS

Property	Result	Original Objective
Light Transmission (1)	74.3 to 86.9%	> 85.0%
Haze (1)	0.9 to 6.8%	< 3.0%
Resistance To Debonding	1 panel no debonding, 5 cycles (#102)	Minimum of 5 cycles without debonding
	1 panel, very slight debonding after 5th cycle (#81) (~0.060 In)	
	2 panels, very slight debonding after 1st cycle, (~0.060 In) No change after 5 cycles (#106 & 115)	
Thickness Tolerance	(+) 3.7 to 7.4% (-) 5.2 to 8.9%	+ 5.0%
Maximum Deviation of Line of Sight	0 to 10 minutes of arc	< 7 minutes of arc
Interlaminar Shear Strength	951 to 1659 psi	> 1000 psi
Ballistic Resistance V_{50}	975 to 1025 FPS	Maximum

(1)Moldings with high haze not included.

The original contractual requirement specified that the polyolefin panels were to be molded "net" to prevent delamination induced by a machining opeation. Cutting to dimensions would be permitted if it was demonstrated that such cutting resulted in no edge delamination.

During the Task III effort it was determined that molded polyolefin panels could be machined without causing delamination. Figure 6 shows a typical panel machining operation. To prevent delamination, a 0.125 inch thick sheet of acrylic is placed on each side of the molded panel. Sufficient pressure is applied to prevent slippage. Routing is then accomplished with an 18,000 RPM hand held router using a 0.500 inch diameter, two flute carbide inlaid router bit. As long as the router bit was kept sharp, there was no delamination.



PANEL MACHINING PROCEDURE

FIGURE 6

Task IV - Protective Covers

The objective of this task was the selection and evaluation of materials to be used as protective covers for the molded polyolefin panels.

In its current form, polyolefin lacks good resistance to ultraviolet exposure and is not recommended for continuous outdoor use.

Polyolefin material, like polycarbonate, requires surface protection when subjected to outdoor exposure.

Many films and sheet materials were considered for possible application as protective covers. In order to keep the overall weight of the composite to a minimum, the following materials were selected for evaluation in Task IV.

- Diamond Shamrock film number NB-81-59-99-5, U.V. stabilized. Nominal thickness 0.0028 inches.
- Polyvinyl Fluoride (PVF) Film, U.V. stabilized. "Tedlar" from DuPont. Nominal thickness 0.001 inches.
- Polymethylmethacrylate (Acrylic) Film, U.V. stabilized. "Korad" from Korad, Inc. a subsidiary of Georgia-Pacific Corp. Nominal thickness 0.003 inches.
- Abrasion Resistant Coating (A.R.C.).

A total of 17 moldings, Trial Numbers 121 through 137, 12 inches by 12 inches by 20 ounces/foot^2, were prepared in Task IV.

Trial Numbers 121, 122, 124, and 126 were molded with Diamond Shamrock film NB-81-59-99-5 (U.V. stabilized) on the exterior surface(s) as follows:

Trial Nos. 121 and 122	Two plies on each surface
Trial Nos. 124 and 126	On ply on one surface only

The addition of the Diamond Shamrock film resulted in moldings of excessive haze. Moldings with two plies of film on each surface had average haze values of 32.3 and 29.6 percent, and the moldings with one ply film on one surface only had average haze values of 14.2 and 14.5 percent.

Because of the resulting high haze, the Diamond Shamrock film was deleted from the program.

Trial Number 127 was molded with Tedlar (PVF) film on each surface. The Tedlar film would not bond to the polyolefin film during the molding cycle. One molding was tried, no trial number, with Tedlar (PVF) and Korad (Acrylic) film on each surface. As with Trial Number 127, the film material would not bond to the polyolefin film during the molding cycle.

Because the Tedlar and Korad Films would not bond to the molded polyolefin, it was decided to laminate the film to the polyolefin with an interlayer. Preliminary studies indicated fair adhesion could be achieved with Polyvinyl Butyral (PVB) or Silicone.

Six moldings, Trial Numbers 112, 118, 120, 128, 129 and 130 were utilized for application of protective covers, with an interlayer. Trial Numbers 118 and 120 were surfaced on both sides with an acrylic film, (Korad), 0.003 inches thick, bonded to the molded EK-500 with Polyvinyl Butyral (PVB). The adhesion was fair. During lamination of Trial No. 120, the glass caul broke on one side, with considerable glass adhering to the composite.

Trial Numbers 112 and 128 were surfaced on both sides with a polyvinyl fluoride film (Tedlar), 0.001 inches thick bonded to the molded EK-500 with PVB. The adhesion was fair, although incomplete bonding was encountered. Trial Numbers 129 and 130 were surfaced on both sides with the Tedlar Film, 0.001 inches thick, bonded to the molded EK-500 with Swedlow Silicone. Although the adhesion was better than that obtained with the PVB, the Tedlar film developed wrinkles during the laminating cycle.

Light transmission and haze was measured on the six surfaced moldings and the results are contained in Table 21. The readings were taken in areas of the composite to avoid, as much as possible, unbonded areas, etc. A comparison of the data was made with the molded panels prior to surfacing.

TABLE 21

LIGHT TRANSMISSION AND HAZE

OF PANELS WITH PROTECTIVE COVERS

TESTING AT +75°F PER ASTM D-1003

KORAD/PVB PROTECTIVE COVERS

Panel Number	1	2	3	4	5	6	7	8	9	(1)
118 LT =	80.9	80.3	79.8	80.2	79.5	79.5	79.4	79.6	80.0	82.7/85.9
H =	9.3	8.4	9.1	8.9	7.4	7.9	8.5	8.7	8.4	2.5/6.7
120 LT =	76.1	-	-	77.6	-	-	78.2	78.7	78.4	81.7/84.8
H =	22.2	-	-	19.4	-	-	14.7	14.0	13.7	2.3/4.8

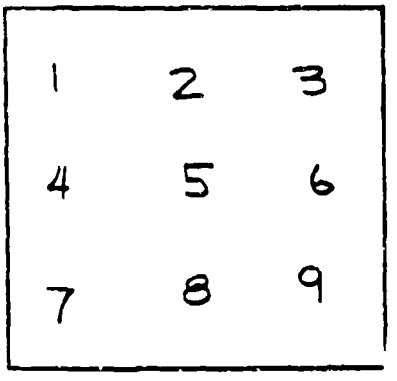
TEDLAR/PVB PROTECTIVE COVERS

112 LT =	81.1	78.4	77.9	80.0	77.9	77.9	79.0	77.9	76.5	79.7/84.4
H =	14.0	18.1	15.4	16.0	16.0	15.8	14.2	15.8	14.6	1.6/4.9
128 LT =	83.0	82.7	82.2	82.6	81.6	80.3	81.3	81.2	80.6	82.8/86.1
H =	12.7	12.7	13.5	13.3	12.9	13.4	12.6	12.0	12.8	3.3/4.7

TEDLAR/SILICONE PROTECTIVE COVERS

129 LT =	79.8	78.6	78.4	78.7	77.1	79.2	77.1	78.6	77.4	82.7/85.8
H =	20.8	16.5	17.4	17.6	17.1	17.9	18.4	17.7	16.8	3.0/4.2
130 LT =	80.7	78.8	77.4	80.5	78.2	77.2	80.1	79.3	79.3	82.8/86.1
H =	19.7	19.9	24.4	16.2	21.5	18.3	17.9	16.1	19.9	3.3/4.7

(1) Minimum to maximum readings of light transmission and haze - prior to application of protective covers.



Location of light transmission and haze readings

Molding trials Number 123, 125, 131 and 132 were coated with Swedlow protective coating SS-6590. All four panels exhibited warpage, due to the method used to support the panels during cure. The protective coating had reasonably good adhesion to the molded polyolefin.

Light transmission and haze was measured on the four protective coated moldings and the results are contained in Table 22.

TABLE 22

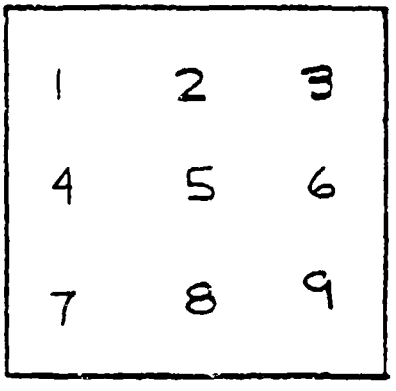
LIGHT TRANSMISSION AND HAZE

OF PROTECTIVE COATED PANELS

TESTING AT +75°F PER ASTM D-1003

	LOCATION OF READING									
Panel Number	1	2	3	4	5	6	7	8	9	(1)
123 LT =	88.0	87.2	86.4	85.1	87.7	85.5	84.8	84.8	86.2	83.2/85.4
H =	2.6	2.5	2.4	2.4	2.4	2.7	2.7	2.2	2.2	3.0/4.0
125 LT =	86.2	85.9	86.1	85.5	84.8	86.1	86.8	86.2	87.5	82.8/84.2
H =	2.3	3.0	2.7	2.0	2.0	1.8	2.2	2.2	2.2	2.5/3.2
131 LT =	87.3	85.0	84.1	82.7	83.4	85.6	85.7	83.9	84.0	82.6/86.3
H =	1.5	1.3	1.3	1.7	1.4	1.3	1.7	1.7	2.0	2.3/4.9
132 LT =	85.1	83.0	83.1	83.2	82.4	84.8	85.5	84.4	84.2	81.0/84.9
H =	2.3	5.4	2.9	2.3	5.2	1.8	1.6	1.8	1.7	3.1/6.2

(1) Minimum to maximum readings of light transmission and haze - prior to application of protective coating.



Location of light transmission and haze readings

All the molded polyolefin panels with Korad and Tedlar protective covers experienced a decrease in light transmission and an increase in haze, whereas all the molded polyolefin panels with the protective coating experienced an increase in light transmission and a decrease in haze.

Five molded polyolefin panels, 12 inches by 12 inches by 20 ounces/foot^2, with surface protection, were submitted to AMMRC for evaluation. Three panels had Korad and Tedlar protective covers and two had a protective coating.

An examination of the five protected panels, and the data contained in Tables 21 and 22, resulted in the selection of the coating as the means of protecting the full-size windows to be produced in Task VI.

A summary of the Task IV molding trials, Numbers 121 through 137, is contained in Appendix A.

The actual molding cycles are contained in Appendix B as Figures IV-1 through IV-10.

The individual light transmission and haze readings obtained on each of the moldings, Trial Numbers 121 through 137, are contained in Appendix C.

It appears that the high haze of moldings 134, 135, 136 and 137 was a result of localized hot spots during molding. A second thermocouple was used in molding Number 137 in the location of the high haze of moldings 134, 135 and 136. As shown in Appendix A, Task IV and Appendix B, Figure IV-10, the high haze area reached a maxiumum temperature of 9°F above the control area.

The localized hot spots were apparently a result of the molding tool, since the haze pattern tended to follow the water cooling pattern.

However, since the requirement for 12" x 12" panels was fulfilled, rework of the molding tool was not conducted.

Task V - Process Specifications

The objective of this task was the preparation of Process Specifications that describe the selected starting materials and detail the procedures for converting oriented film into bonded sheet of optimal ballistics, optical and debonding characteristics.

The following specifications were prepared, based on the data generated in Tasks I through IV, and are included in Appendix E.

Engineering Report No. 990

"Material Procurement Specification - Polypropylene Film for Transparent Armor"

This specification establishes the material requirements to be acceptable for the production of transparent film armor and provides the

receiving procedure and test methods to be employed in assuring conformance.

Engineering Report No. 991

"Process Specification-Production of Transparent Polyolefin Film Armor"

This specification describes the materials and procedures required for converting polyolefin film into bonded sheet.

The following drawings were prepared during the performance of this contract and are included in Appendix F.

Swedlow Number 77050

Assembly-Chase Mold (12"x12") - AMMRC. Transparent Armor Test Plaques.

Swedlow Number 80025

Assembly-Chase Mold-AMMRC. Transparent Armor Windows.

In addition, the following drawing is included in Appendix F for reference purposes.

AMMRC CD-1

Transparent Polypropylene Film Windows.

Task VI - Production of Film and Bonded Sheet

The objective of this task was to produce film and molded sheet in accordance with the process specification generated in Task V.

A chase mold with inside dimensions of 16" x 27" was fabricated in accordance with Swedlow Drawing 80025. Since it had been previously determined that water cooling of the mold was not required to produce clear moldings, such cooling was not incorporated in the tool.

A total of 19 moldings, Trial Numbers 138 through 156, were prepared in accordance with Engineering Report Number 991.

Trial Numbers 138 and 139, which were 12 inches by 12 inches by 20 ounces/foot^2, were used to verify the molding cycle. Both moldings were clear, indicating satisfactory molding conditions. The individual light transmission and haze readings obtained on molding Trial Numbers 138 and 139 are contained in Appendix C.

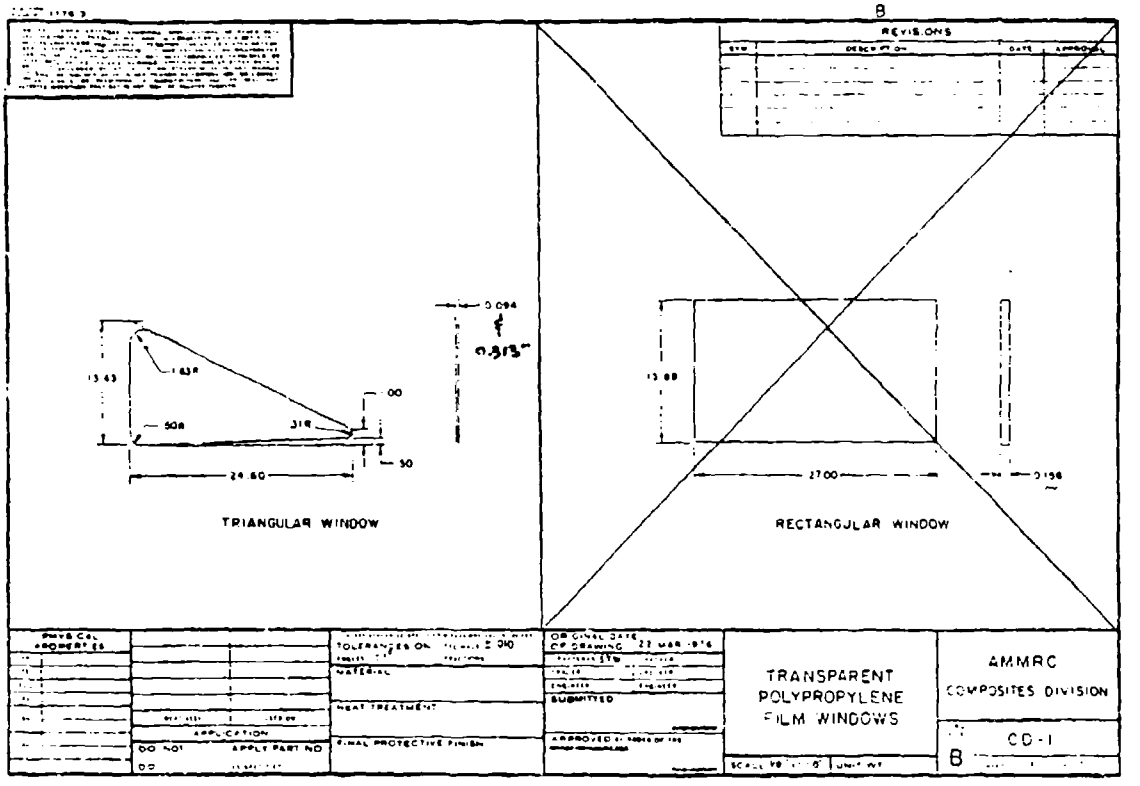
Trial numbers 140 through 156 were 16" x 27" moldings, from which triangular windows per AMMRC drawing CD-1 could be obtained. Each 16" x 27" molding was large enough to obtain two windows. Trial numbers 140 through 149 were nominal

0.094 inch thick, (7.12 ounces/foot^2), and trial numbers 150 through 156 were nominal 0.313 inch thick, (23.71 ounces/foot^2).

As reported in Task IV, it was determined that the full-size triangular windows would be coated with a protective coating.

Molding trials 140, 141, 144, 147, 149 and 156 had varying defects such as delamination, wrinkles and dimples which made them unsuitable as windows. These moldings were used for protective coating evaluations.

The moldings to be utilized as windows, moldings 142, 143, 145, 146, 148, 150,151, 152, 153, 154 and 155 were coated, in the full 16" x 27" size, with Swedlow's protective coating SS-6590. After coating and curing both sides, triangular windows per AMMRC drawing CD-1, as shown in Figure 7, were machined from each molding. Each molding yielded two windows, except molding No. 151, where only one window could be obtained due to slippage during machining.



AMMRC DRAWING CD-1

FIGURE 7

Light transmission and haze was measured on the 21 individual CD-1 triangular windows and the results are contained in Table 23.

TABLE 23

LIGHT TRANSMISSION AND HAZE

OF TRIANGULAR WINDOWS

TESTING AT +75°F PER ASTM D-1003

Panel Number	Nominal Thickness (Ins.)		Location of Readings 1	2	3	4
142-1	0.094	LT =	89.8	91.1	91.2	88.4
		H =	2.0	3.4	3.2	3.1
142-2	0.094	LT =	89.5	89.6	89.1	88.0
		H =	2.2	2.4	4.8	2.0
143-1	0.094	LT =	90.6	90.5	90.4	89.3
		H =	2.3	4.4	2.6	2.4
143-2	0.094	LT =	90.5	90.4	90.5	89.8
		H =	2.7	2.4	3.1	2.2
145-1	0.094	LT =	90.7	91.1	89.9	89.5
		H =	1.9	2.6	2.4	2.7
145-2	0.094	LT =	90.0	90.5	91.0	89.6
		H =	3.0	3.2	3.0	2.0
146-1	0.094	LT =	90.1	90.2	90.6	89.7
		H =	2.6	2.7	2.9	2.8
146-2	0.094	LT =	90.5	90.8	90.6	89.6
		H =	2.8	3.8	3.6	3.2
148-1	0.094	LT =	88.5	89.8	88.9	88.0
		H =	4.3	5.3	4.1	5.2
148-2	0.094	LT =	89.4	90.2	90.1	88.6
		H =	2.8	2.2	1.9	2.9
150-1	0.313	LT =	83.5	84.4	84.5	83.2
		H =	4.1	4.0	3.8	3.6
150-2	0.313	LT =	84.1	84.4	84.6	83.4
		H =	3.3	3.6	4.4	5.3
151-1	0.313	LT =	83.8	84.0	84.6	83.8
		H =	4.3	4.6	5.1	4.3

TABLE 23 (CONT'D)

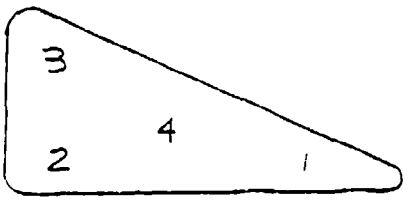
Panel Number	Nominal Thickness (Ins.)		Location of Readings 1	2	3	4
152-1	0.313	LT =	85.0	84.9	85.1	84.4
		H =	5.5	5.7	6.2	4.8
152-2	0.313	LT =	85.0	85.7	84.9	84.6
		H =	4.9	5.6	5.0	5.5
153-1	0.313	LT =	85.6	85.1	84.1	84.6
		H =	5.0	4.9	5.4	5.1
153-2	0.313	LT =	85.5	85.2	85.4	85.7
		H =	5.0	5.2	5.4	5.1
154-1	0.313	LT =	84.7	85.2	85.7	83.7
		H =	4.5	5.9	4.9	4.3
154-2	0.313	LT =	84.4	83.7	84.6	83.2
		H =	2.8	3.7	4.0	2.6
155-1	0.313	LT =	84.9	86.3	84.8	84.2
		H =	4.8	5.2	4.9	4.9
155-2	0.313	LT =	84.8	85.0	84.2	83.8
		H =	5.1	5.8	5.1	5.1

The 21 individual CD-1 triangular windows were dimensionally inspected for conformance to AMMRC drawing CD-1. The results obtained are contained in Table 24.

TABLE 24

DIMENSIONAL RESULTS OF TRIANGULAR WINDOWS

Panel Number	Thickness (Inches) 1	2	3	4	Reqt.	Dimensions (Inches) 24.60	13.63	0.50	1.00	0.31R	0.50R	1.03R
142-1	.100	.080	.087	.116	.094	24.51	13.55	.38	.95	ok	ok	ok
142-2	.103	.089	.090	.119	.094	24.55	13.58	.40	.98	ok	ok	ok
143-1	.095	.087	.099	.115	.094	24.52	13.55	.40	.89	ok	ok	ok
143-2	.104	.090	.091	.114	.094	24.50	13.54	.40	.93	ok	ok	ok
145-1	.096	.087	.091	.112	.094	24.49	13.60	.40	.97	ok	ok	ok
145-2	.095	.085	.095	.111	.094	24.50	13.60	.40	1.00	ok	ok	ok
146-1	.090	.083	.087	.107	.094	24.51	13.58	.44	.95	ok	ok	ok
146-2	.092	.091	.093	.109	.094	24.54	13.57	.45	.97	ok	ok	ok
148-1	.091	.094	.098	.111	.094	24.50	13.55	.47	1.00	ok	ok	ok
148-2	.096	.089	.100	.121	.094	24.53	13.58	.40	.94	ok	ok	ok
150-1	.291	.280	.302	.314	.313	24.50	13.56	.36	.86	ok	ok	ok
150-2	.307	.288	.282	.330	.313	24.54	13.55	.42	.94	ok	ok	ok
151-1	.292	.292	.289	.324	.313	24.51	13.58	.40	.95	ok	ok	ok
152-1	.297	.285	.293	.329	.313	24.53	13.60	.40	.95	ok	ok	ok
152-2	.302	.302	.297	.333	.313	24.53	13.61	.40	.95	ok	ok	ok
153-1	.318	.308	.312	.348	.313	24.49	13.57	.42	.95	ok	ok	ok
153-2	.325	.300	.311	.348	.313	24.51	13.55	.40	.93	ok	ok	ok
154-1	.305	.292	.291	.331	.313	24.51	13.60	.40	.95	ok	ok	ok
154-2	.307	.309	.307	.338	.313	24.53	13.57	.41	.95	ok	ok	ok
155-1	.324	.310	.310	.350	.313	24.51	13.55	.41	.89	ok	ok	ok
155-1	.316	.302	.326	.337	.313	24.51	13.54	.41	.90	ok	ok	ok



Location of light transmission, haze and thickness readings

The following 20 CD-1 triangular windows were delivered to AMMRC.

- Ten windows nominal 0.094" thick, (7.12 ounces/foot^2). Two each Trial No. 142, 143, 145, 146 and 148.
- Ten windows nominal 0.313" thick, (23.71 ounces/foot^2). Two each Trial No. 150, 152, 153, 154 and 155.

In addition, 15 rolls, 0.001" x 32" wide of Hercules EK-500 Film was delivered to AMMRC. The total net weight was 860 pounds.

A summary of the Task VI molding trials, Numbers 138 through 156, is contained in Appendix A.

The actual molding cycles are contained in Appendix B as Figures VI-1 through VI-19.

CONCLUSIONS

Based on the results obtained during the performance of this program, the following conclusions can be reached.

- The basic objective of this program, the determination of the optimum processing condition for oriented polyolefin film, has been successfully accomplished.
- The manufacturing technology has been established for the production of transparent polyolefin film armor having acceptable levels of light transmission, haze, interply strength, surface protection, optical deviation, machinability and ballistic performance.
- As a direct result of the process optimization developed during this program, Swedlow produced triangular shaped helicopter windows for evaluation by AMMRC. The production of these windows demonstrated the validity of the production process and the feasibility of process scale up from the 12 inch by 12 inch by 20 ounces/ft^2 size.
- A range of sizes and thicknesses are now capable of being produced in molded oriented polyolefin.

RECOMMENDATIONS

As a result of the work conducted under this contract, the following areas have been identified where further development activity should be considered.

- o Improvement of the ultra-violet resistance of the oriented film.
- o Investigate additional protective covers and protective coatings.
- o Improvement of the bonding capability of the protective covers and protective coatings.
- o Determine practical limits of production, (thickness and size), and effects on optical qualities and ballistic limits.

DELIVERED ITEMS

During the performance of this contract, Task I through Task VI, the following items have been delivered by Swedlow, Inc. to AMMRC.

TASK		ITEM
I	2	Moldings, 12" x 12" x 20 oz/ft^2 of N400 Reference Filmm (#15 and #16).
	2	Layups, 14" x 14" x 20 oz/ft^2 of N400 Reference Film. (Cross-plies, unmolded).
II	33	Moldings, 12" x 12" x 20 oz/ft^2. 2 each N600 (A.C.)(#21 and #23) 2 each Identified as N600 (Rev.), (#25 and #26), are N400 3 each AT61 (#22,#29 and #34) 2 each B503 (#18 and #19) 2 each P 2101 (#32 and #33) 2 each X207 (#37 and #39) 2 each P81B (#38 and #49) 2 each G.E. (#40 and #46) 3 each B500 (#41, #44 and #48) 3 each Identified as N400II (#45, #47 and #52), suspected to be N600 4 each SK300 (#57, #59 #60 and #61) 2 each Dia. Shamrock (#65 and #66) 2 each EK500 (#70 and #71) 2 each El Rexene (#69 and #72)
	15	Layups, 12" x 12" x 20 oz/ft^2. (Cross-plies, unmolded) 1 each P2102, N400 II (Suspected to be N600), N600 (A.C.), N600 (Rev.)(is N400) B503, AT61, G.E., X207, P818, B500, N400, SK300, Dia. Shamrock, EK500 and El Rexene.
III	23	Moldings, 12" x 12" x 20 oz/ft^2 of EK 500 Film. (#76 through #80, #82 through #86, #88 through #91, #93 through #97, #99, #104, #117 and #119,

TASK	ITEM
	2 Layups, 12" x 12" x 20 oz/ft^2. (Unmolded) 1 Cross-plied, 1 not cross-plied.
	Engineering Report No. 948 "Test Procedure for Determining The Optimum Processing Condition For Transparent Polyolefin Film Armor".
IV	5 Moldings, 12" x 12" x 20 oz/ft^2. of EK 500 Film. 2 with SS-6590 protective coating (#131 and #132). 3 with protective covers (#118, #128 and #130).
V	Engineering Report No. 990 "Material Procurement Specification - Polypropylene Film for Transparent Armor".
	Engineering Report No. 991 "Process Specification - Production of Transparent Polyolefin Film Armor".
VI	20 Triangular windows per AMMRC Drawing CD-1.
	10 Windows 0.094" thick. (2 each #142, #143, #145, #146 and #148).
	10 Windows 0.313" thick. (2 each #150, #152 through #155).
	860 pounds of biaxially oriented EK-500 film. (15 rolls 0.001" thick by 32" wide)

REFERENCES

1. Swedlow Technical Proposal 76-0301 dated August 20, 1975 as amended by 76-0301.8 dated January 8, 1976.

2. Contract Number DAAG46-76-C-0034, effective date March 30, 1976, with amendment numbers P00001 and P00002.

3. Progress Report Number 1 dated June 1, 1976 through Number 28 dated March 31, 1981.

4. Alesi, A.L., Ames, R.P., Gagne, R.A., Litman, A.M. and Prifti, J.J., "New Materials and Construction for Improved Helmets", Army Materials and Mechanics Research Center, Watertown, Massachusetts, AMMRC MS 75-9, November 1975.

5. Prifti, J.J., DeLuca, E. and Alesi, A.L. "Hardened Tuned-Walled Plastic Radomes for Military Radars (U)," Army Materials and Mechanics Research Center, Watertown, Massachusetts.

6. Federal Standard 209 - Clean Room and Work Station Requirements, Controlled Environment.

7. ASTM Standards - Methods of Testing.

8. Box, G.E.P. and Behnken, D. W. "Some New Three Level Designs for the Study of Quantative Variables", Technometrics 2, 1960.

9. Davies, O.L., Editor, "The Design and Analysis of Industrial Experiments", Longman Group Limited, London and New York. Second Edition, 1978.

10. Military Specification MIL-P-25690A "Plastic, Sheets and Parts, Modified Acrylic Base, Monolithic, Crack Propagation Resistant".

APPENDIX A

SUMMARY OF MOLDING TRIALS

TASK I - Trial Numbers 1 through 16

TASK II - Trial Numbers 17 through 73

TASK III - Trial Numbers 74 through 120

TASK IV - Trial Numbers 121 through 137

TASK VI - Trial Numbers 138 through 156

TASK I

PREPARATION OF REFERENCE FILM AND SHEET

Trial Numbers 1 through 16

TASK I

PREPARATION OF REFERENCE FILM AND SHEET

SUMMARY OF MOLDING TRIALS

PROPERTY	TRIAL NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
Film Type	N400	N400	N400	N400	N400	N400	N400	N400	N400	N600[1]	N400	N500[1]
Number of Plies	200	212	240	240	236	238	239	252	252	100	252	100
Drying Temp. (°F)	220	220	160	160	160	160	190/205	200	[4]	200	R.T.	R.T.
Drying Time (Hrs.)	5.5	6.5	21	40	45	63	2.5	6	[4]	6	6	6
Vacuum (Hrs.)	No	No	21	40	45	63	2.5	6 @ R.T.	--	6 @ R.T.	6 @ R.T.	6 @ R.T.
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000	--	2000	2000	2000
Heat Up (Minutes)	24	27	[3]	24	22	24	29	25	--	25	15	15
Dwell (Minutes)	11	5	[3]	10	5	6	60	10	--	15	10	10
Maximum Temp. (°F)	328	330	354	327	319	317	319	320	--	322	318	318
Thickness (In.)	.235	.260[2]	.170/ .252	.245/ .303	.220/ .275	.220/ .300	.210/ .270	.150	--	.230	.135	.105
Light Trans. (%)	12	15	30	20	32	36	20	43/56	--	35/42	47/55	57/62
Date	6/28	6/29	8/4	8/5	8/5	8/6	8/11	8/18	--	8/25	8/26	8/27

[1] Film identified as Hercules N600, Rolled by Revere, is N400
[2] CO_2 cooled
[3] Temperature overrun - part badly flowed. Extruded through thermocouple opening.
[4] Oven override during drying cycle

TASK I (Cont) PREPARATION OF REFERENCE FILM AND SHEET

SUMMARY OF MOLDING TRIALS

PROPERTY	TRIAL NUMBER 13	14	15	16
Film Type	B-503	N-400	N-400	N-400
Number of Plies	242	240	232	232
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.
Drying Time (Hrs.)	6	6	6	6
Vacuum	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000
Heat Up (Minutes)	35	25	35	30
Dwell (Minutes)	10	15	15	15
Maximum Temp. (°F)	290	314	314	314
Thickness (In.)	0.150	-	-	-
or				
Weight (oz/ft^2)	-	21.2	20.24	20.53
Light Trans. (%)	76/80	30/40	40/53	40/48
Haze (%)		75/80		
Date	9-2	9-28	9-28	9-28

TASK II

EFFECT OF FILM CHARACTERISTICS

Trial Numbers 17 through 73

TASK II

EFFECT OF FILM CHARACTERISTICS

SUMMARY OF MOLDING TRIALS

PROPERTY	TRIAL NUMBER 17	18	19	20	21	22
Film Type	B-503	B-503	B-503	N-600[1]	N-600[1]	AT-61
Number of Plies	226	246	226	184	184	254
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hrs.)	6	6	6	24	24	24
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	25	30	25	20	16	14
Dwell (Minutes)	10	15	25	8	12	14
Maximum Temp. (°F)	293	292	293	322	327	330
Weight (oz/ft^2)	20.74	21.02	20.42	20.51	20.7	20.06
Light Trans. (%)	83.6/ 89.2	84.7/ 87.5	85.5/ 86.7	88.8/ 94.2	87.6/ 91.3	63.7/ 73.5
Haze (%)	3.9/7.8	4.0/4.6	3.0/4.3	4.3/6.5	4.9/8.3	38.7/46.2
Date	9-29	9-29	9-29	10-29	10-29	10-29

TASK II (Cont.) Page 2 EFFECT OF FILM CHARACTERISTICS

SUMMARY OF MOLDING TRIALS

	TRIAL NUMBER							
PROPERTY	23	24	25	26	27	28	29	30
Film Type	N600[1]	N600[1]	N600[2]	N600[2]	N600[2]	AT-61	AT-61	P2102
Number of Plies (or Unit Weight)	184	184	580 Gms	585 Gms	585 Gms	250	250	140
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hrs.)	72	72	72	96	96	15	16	20
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	18	16	16	27	23	21	30	24
Dwell (Minutes)	9	11	10	16	8	15	8	12
Maximum Temp. (°F)	330	331.5	328.5	317	311.5	322	324	323
Weight (oz/ft^2)	20.38	20.37	20.64	21.37	20.66	18.86	18.34	20.35
Light Trans. (%)	88.4/ 89.3	87.2/ 90.1	17.2/ 25.5	23.3/ 35.2	21.7/ 38.7	68.0/ 75.2	69.5/ 74.7	80.7/ 83.2
Haze (%)	4.9/7.5	1.4/6.3	96.5/ 100.0	76.6/ 90.8	73.6/ 88.0	37.6/ 41.6	34.8/ 40.9	23.0/ 25.9
Date	11-1	11-1	11-1	11-2	11-2	11-3	11-3	11-3

SUMMARY OF MOLDING TRIALS

PROPERTY	TRIAL NUMBER 31	32	33	34	35	36	37	38	39	40	41	42
Film Type	P2102	P2102	P2102	AT-61	AT-61	G. E.	X-207	P-81-B	X-207	G. E.	B-500	N400[3]
Number of Plies (or Unit Weight)	140	140	116	250	250	242	264	222	264	242	220	306
Drying Temp. (°F)	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.
Drying Time (Hrs.)	336	336	96	504	504	17	19	23	66	70	17	20
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	26	16	18	18	22	20	16	14	15	15	16	13
Dwell (Minutes)	10	11	10	6	13	8	8	12	12	11	12	14
Maximum Temp. (°F)	323.5	323	321.5	321.5	330	328	327.5	326.5	328	327	326	326.5
Weight (oz/ft²)	20.28	20.39	20.18	18.9	18.8	20.07	19.9	20.7	20.04	19.82	20.9	20.3
Light Trans. (%)	79.3/ 81.7	78.6/ 81.1	79.4/ 81.0	72.7/ 74.5	66.4/ 73.0	79.6/ 81.4	78.0/ 80.4	71.5/ 74.0	76.1/ 78.4	80.5/ 82.3	82.9/ 84.0	86.4/ 87.5
Haze (%)	23.8/ 26.9	23.3/ 26.5	23.1/ 24.5	33.7/ 36.2	35.1/ 42.2	8.3/ 9.1	4.8/ 5.9	6.6/ 10.8	6.3/ 7.6	5.4/ 8.3	3.4/ 4.2	11.2/ 16.8
Date	12-6	12-6	12-7	12-7	12-7	12-8	12-8	12-8	12-9	12-9	12-14	12-14

SUMMARY OF MOLDING TRIALS

	TRIAL NUMBER										
PROPERTY	43	44	45	46	47	48	49	50	51	52	53
Film Type	P-81-B	B-500	N400[3]	G. E.	N400[3]	B-500	P-81-B	X-207	N400[3]	N400[3]	B-500
Number of Plies (or Unit Weight)	588 Gms	214	302	264	300	220	222	264	300	300	240
Drying Temp. (°F)	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.
Drying Time (Hrs.)	22	42	45	66	68	69	88	90	12	25	27
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	14	16	17	16	15	13	16	15	14	15	15
Dwell (Minutes)	10	10	12	8	10	14	10	12	13	12	14
Maximum Temp. (°F)	325.5	327	328	328	328	327.5	327	326	328	329	329
Weight (oz/ft^2)	20.6	20.6	20.4	19.6	20.3	20.4	20.4	20.4	20.4	20.2	20.5
Light Trans. (%)	72.6/ 73.5	82.7/ 83.0	86.2/ 87.4	79.6/ 80.6	87.4/ 88.2	82.4/ 83.3	72.5/ 73.7	79.2/ 84.6	84.1/ 85.7	85.3/ 87.5	83.7/ 84.1
Haze (%)	8.6/ 10.5	4.1/ 5.2	14.8/ 23.5	4.2/ 4.9	20.9/ 25.5	3.9/ 4.4	7.8/ 8.6	6.3/ 7.4	20.0/ 26.5	19.6/ 28.1	3.3/ 4.3
Date	12-14	12-15	12-15	12-20	12-20	12-20	12-21	12-21	12-28	12-28	12-28

SUMMARY OF MOLDING TRIALS

	TRIAL NUMBER								
PROPERTY	54	55	56	57	58	59	60	61	62
Film Type	SK-300-2	SK-300-2	SK-300-2	SK-300-2	SK-300-2	SK-300-2	SK-300-2	SK-300-2	SK-300-2
Number of Plies (or Unit Weight)	90	90	90	90	90	90	90	90	90
Drying Temp. (°F)	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.	R. T.
Drying Time (Hrs.)	19	21	45	51	22	25	49	51	70
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	16	22	22	21	19	15	16	16	16
Dwell (Minutes)	12	14	20	14	6	8	8	8	12
Maximum Temp. (°F)	329.5	340	356.6	349.5	345	344	343.3	344	343
Weight (oz/ft^2)	20.4	20.45	20.6	20.5	20.3	20.4	20.3	20.2	20.5
Light Trans. (%)	86.2/ 88.2	85.4/ 87.2	37.3/ 39.7	65.0/ 69.5	81.8/ 83.6	82.4/ 83.8	83.3/ 84.8	83.3/ 84.1	83.9/ 87.1
Haze (%)	7.0/ 10.8	7.7/ 9.4	99.0/ 100	24.5/ 27.3	11.4/ 14.5	6.7/ 8.0	5.8/ 6.7	6.0/ 8.3	7.0/ 7.9
Date	1-5	1-5	1-6	1-6	1-12	1-12	1-13	1-13	1-14

SUMMARY OF MOLDING TRIALS

PROPERTY	TRIAL NUMBER 63	64	65	66	67	68
Film Type	ER[4]	D.S.[5]	D.S.	D.S.	E.R.	D.S.
Number of Plies (or Unit Weight)	575 Gms.	580 Gms.	575 Gms.	570 Gms.	568 Gms.	570 Gms.
Drying Temp. (^{O}F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hours)	12	14	36	38	40	60
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	15	15	20	18	25	20
Dwell (Minutes)	15	10	8	17	12	14
Maximum Temp. (^{O}F)	346	332	320	323	328	326
Weight (oz/ft^2)	20.4	18.6	20.3	20.0	20.0	20.1
Light Trans. (%)	87.7/ 91.5	20.7/ 43.0	32.5/ 41.5	0/ 21.2	91.5	0
Haze)%)	13.5/ 18.5	73.6	35.4/ 44.4	53.6/ 71.6	14.7	67.4/ 71.5
Date	9-26	9-26	9-27	9-27	9-27	9-28

 EFFECT OF FILM CHARACTERISTICS

SUMMARY OF MOLDING TRIALS

PROPERTY	TRIAL NUMBER 69	70	71	72	73
Film Type	E.R.	EK-500	EK-500	E. R.	EK-500
Number of Plies (or Unit Weight)	568 Gms.	570 Gms.	570 Gms.	572 Gms.	570 Gms.
Drying Temp. (^{o}F)	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hrs)	62	64	66	108	110
Vacuum	Yes	Yes	Yes	Yes	Yes
Pressure (psi)	2000	2000	2000	2000	2000
Heat Up (Minutes)	17	19	17	17	14
Dwell (Minutes)	18	12	15	12	12
Maximum Temp. (^{o}F)	335	330.5	332	351	348
Weight(oz/ft^2)	20.0	20.1	20.14	20.1	20.1
Light Trans. (%)	88.8/ 92.0	87.2/ 89.8	87.5/ 88.8	54.7/ 60.0	84.8/ 86.7
Haze (%)	11.2/ 18.4	0/1.5	1.8/3.6	38.2/ 44.0	3.4/8.6
Date	9-28	9-28	9-28	10-3	10-3

1 Hercules N-600 rolled by American Can
2 Film identified as Hercules N-600, rolled by Revere, is N400
3 Film identified as Hercules N-400 Clear rolled by Revere (Swedlow Designation Type II) suspected to be N600
4 El Rexene Film No. PP-41-6300-4153
5 Diamond Shamrock Film No. NB-81-59-99-3

TASK III

MOLDING FLAT SHEET

Trial Numbers 74 through 120

TASK III

MOLDING FLAT SHEET

SUMMARY OF MOLDING TRIALS
(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 74	75	76	77	78	79	80	81	82	83
Number of Plies (or Unit Weight)	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hours)	36	38	110	115	300	304	168	171	216	220
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	1550	1550	1550
Heat Up (Minutes)	20	27	13	21	21	24	27	42	(1)	25
Dwell (Minutes)	10	14	11	8	8	15	4	32	--	60
Maximum Temp. (°F)	330	331.5	331.5	324.5	321	328	304	331	352	304
Weight (oz/ft^2)	20.1	20.1	20.1	20.2	20.1	20.1	20.1	20.2	10.1	20.1
Light Trans. (%)	78.2/83.4	80.5/83.3	80.6/83.8	81.6/84.1	82.1/84.3	82.5/83.9	84.3/86.2	81.9/84.8	49.7/58.4	82.6/84.4
Haze (%)	4.1/25.4	3.3/5.7	2.6/5.8	2.4/5.4	4.0/4.5	4.5/5.8	3.1/5.1	2.3/5.2	--	2.8/5.6
Date	6-8	6-8	6-11	6-11	6-18	6-18	6-27	6-27	6-28	6-28

TASK III (Cont) Page 2 MOLDING FLAT SHEET

SUMMARY OF MOLDING TRIALS

(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 84	85	86	87	88	89	90	91	92
Number of Plies (or Unit Weight)	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hours)	244	200	200	720	450	400	400	400	60
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	1550	1550	100	1550	1550	1550	500	500	500
Heat Up (Minutes)	35	31	25	27	35	44	30	35	40
Dwell (Minutes)	30	30	30	31	30	1	30	1	60
Maximum Temp. (°F)	331	332	306	331.5	332	348.5	349(3)	331.5	333
Weight (oz/ft^2)	20.1	20.0	20.1(2)	20.3	20.1	20.1	20.1	20.1(4)	20.1
Light Trans. (%)	82.3/84.4	80.0/81.3	78.5/79.3	83.6/86.3	82.3/85.0	77.3/82.1	33.0/72.6	80.6/83.3	-(5)
Haze (%)	3.3/6.7	3.0/6.4	6.4/7.7	2.6/7.0	2.7/7.3	5.2/8.5	6.5/92.8	2.8/8.0	-(5)
Date	6-29	6-29	6-29	8-7	8-8	8-9	8-9	8-9	8-13

SUMMARY OF MOLDING TRIALS
(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 93	94	95	96	97	98	99
Number of Plies (or Unit Weight)	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS	570 GMS
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hours)	60	100	180	180	200	200	260
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	500	750	3000	3000	3000	3000	3000
Heat Up (Minutes)	37	50	18	19	45	45	30
Dwell (Minutes)	60	60	30	1	60	30	30
Maximum Temp. (°F)	332	332	306	302	330	350(3)	350
Weight (Oz/Ft^2)	20.1(4)	20.1	20.1	19.9	20.0	19.2	19.9
Light Trans. (%)	54.7/79.0	81.8/84.5	81.6/83.2	82.4/84.3	80.1/82.5	55.5/65.2	72.3/75.3
Haze (%)	8.7/74.8	3.3/6.0	2.9/4.5	2.4/4.6	2.8/7.0	51.7/88.6	6.4/7.3
Date	8-13	8-15	8-22	8-22	8-24	8-24	8-27

SUMMARY OF MOLDING TRIALS

(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 100	101	102	103	104	105
Number of Plies (or Unit Weight)	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hours)	800 +	600 +	800 +	800 +	600 +	600 +
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	20	20	15	15	15	15
Dwell (Minutes)	30	30	30	30	30	30
Maximum Temp. (°F)	339	338	334	333	334	333
Weight (Oz/Ft^2)	20.1	20.1	20.1	20.1	20.0	20.0
Light Trans. (%)	72.3/83.3	74.3/83.4	79.5/84.9	80.1/84.5	78.6/82.9	78.5/83.3
Haze (%)	2.5/9.1	3.7/6.7	3.5/6.8	2.1/4.6	3.0/5.0	3.2/5.7
Date	2-28	2-28	2-29	2-29	2-29	2-29

TASK III (Cont) Page 5 MOLDING FLAT SHEET

SUMMARY OF MOLDING TRIALS

(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 106	107	108	109	110	111	112	113
Number of Plies (or Unit Weight)	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hours)	600 +	36	36	40	140 +	60 +	80 +	70 +
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	10	10	10	10	10	20	10	10
Dwell (Minutes)	30	30	30	30	30	30	40	45
Maximum Temp. (°F)	332	332	335	334	335	338	337	337
Weight (Oz/Ft^2)	20.0	20.1	20.1	20.1	20.1	20.1	20.0	20.1
Light Trans. (%)	77.8/82.7	81.1/85.0	79.3/86.2	81.3/86.7	62.7/82.7	77.5/84.7	79.7/83.7	72.2/85.1
Haze (%)	3.2/5.7	3.0/11.9	4.0/25.7	2.6/12.9	4.3/91.3	3.4/5.9	1.6/4.9	4.1/63.9
Date	3-3	3-5	3-5	3-5	3-10	3-10	3-10	3-11

SUMMARY OF MOLDING TRIALS

(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 114	115	116	117	118	119	120
Number of Plies (or Unit Weight)	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms	570 Gms
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hours)	90 +	60 +	60 +	60 +	80 +	80 +	400 +
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	10	30	15	15	15	15	10
Dwell (Minutes)	40	30	30	30	30	30	30
Maximum Temp (°F)	335	339	338	338	338	338	339
Weight (Oz/Ft^2)	20.1	20.1	20.1	20.1	20.1	20.1	20.1
Light Trans. (%)	75.8/84.9	81.4/86.9	82.1/86.0	82.3/84.6	82.7/85.9	81.6/85.0	81.7/84.8
Haze (%)	2.9/56.6	0.9/3.8	2.2/4.6	1.4/4.5	2.5/6.7	2.6/4.9	2.3/4.8
Date	3-12	4-3	4-3	4-3	4-4	4-4	4-4

(1) Objective temperature, 360°F. Melt at 352°F.
(2) Shrank to 10 11/16 x 11 1/16 during molding.
(3) Started to melt.
(4) Shrank to 11 3/4 x 11 3/4 during molding.
(5) Caul plate left off - L.T. and haze not measured.

TASK IV

PROTECTIVE COVERS

Trial Numbers 121 through 137

TASK IV

PROTECTIVE COVERS

SUMMARY OF MOLDING TRIALS

(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 121	122	123	124	125	126	127	128	129
Number of Plies (or Unit Weight, GMS)	570	570	570	570	570	570	570	570	570
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hours)	390+	380+	400+	400+	400+	400+	60	400+	400+
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	15	15	15	15	15	15	15	15	15
Dwell (Minutes)	30	30	30	30	30	30	30	30	30
Maximum Temp. (°F)	339	334	334	333	333	334	334	338	334
Weight (oz/ft^2)	20.0	20.0	20.1	20.1	20.1	20.1	20.1	20.1	20.1
Light Trans. (%)	76.7/ 79.9	79.6/ 81.7	83.2/ 85.4	82.2/ 84.2	82.8/ 84.2	80.5/ 82.9	83.0/ 86.8	82.8/ 86.1	82.7/ 85.8
Haze (%)	[1]26.8/ 37.1	[1]27.8/ 31.9	3.0/ 4.0	[1]12.2/ 16.1	2.5/ 3.2	[1]12.4/ 16.9	6.1/ 7.6	3.3/ 4.7	3.0/ 4.2
Date	6-10	6-10	6-12	6-12	6-13	6-13	6-18	7-9	7-9

SUMMARY OF MOLDING TRIALS

(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 130	131	132	133	134	135	136	137
Number of Plies (or Unit Weight, GMS)	570	570	570	570	570	570	570	570
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hrs.)	400+	400+	400+	400+	450+	450+	450+	450+
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	15	15	15	20	15	15	15	15
Dwell (Minutes)	30	30	30	30	30	30	30	30
Maximum Temp. (°F)	335	336	345	332	340	346	334	339/330[2]
Weight (oz/ft^2)	20.0	20.0	20.0	20.6	20.0	20.1	20.1	20.1
Light Trans. (%)	82.6/ 86.5	82.6/ 86.3	81.0/ 84.7	84.1/ 86.5	80.4/ 85.4	65.7/ 84.8	72.8/ 84.4	75.3/ 84.4
Haze (%)	2.3/4.0	2.3/4.9	3.1/6.2	2.5/5.2	2.2/31.2	3.0/41.7	2.4/59.2	2.9/38.9
Date	7-10	7-10	7-11	7-11	7-14	7-14	7-14	7-14

NOTES:

[1] Incorporated Diamond Shamrock UV film on each surface.

[2] Two thermocouples placed in molding.

TASK VI

PRODUCTION OF FILM AND BONDED SHEET

Trial Numbers 138 through 156

TASK VI

PRODUCTION OF FILM AND BONDED SHEET

SUMMARY OF MOLDING TRIALS

(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 138	139	140	141	142	143	144	145	146	147	148
Number of Plies (or Unit Weight, GMS)	570	570	96	94	105	104	105	105	105	105	105
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hrs)	50+	60+	400+	400+	400+	400+	400+	400+	400+	400+	400+
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	35	35	20	30	20	20	20	15	20	15	15
Dwell(Minutes)	30	30	10	30	30	30	30	30	30	30	30
Maximum Temp.(°F)	341	338	349	336	341	338	334	336	332	337	337
Weight (oz/ft^2)	20.1	20.1	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Light Trans. (%)	83.2/ 86.1	82.7/ 85.6	[3]	[3]	88.0/ 91.2	89.3/ 90.6	[3]	89.5/ 91.1	89.6/ 90.8	[3]	88.0/ 90.2
Haze (%)	3.2/ 4.6	2.4/ 5.7	[3]	[3]	2.0/ 4.8	2.2/ 4.4	[3]	1.9/ 3.2	2.6/ 3.8	[3]	1.9/ 5.3
Date	8-25	8-26	11-30	12-1	12-2	12-2	12-2	12-3	12-3	12-3	12-4

SUMMARY OF MOLDING TRIALS

(HERCULES EK-500 FILM)

PROPERTY	TRIAL NUMBER 149	150	151	152	153	154	155	156
Number of Plies (or Unit Weight, GMS)	105	324	324	324	324	324	324	324
Drying Temp. (°F)	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.	R.T.
Drying Time (Hrs)	400+	400+	500+	500+	500+	500+	500+	500+
Vacuum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure (Psi)	2000	2000	2000	2000	2000	2000	2000	2000
Heat Up (Minutes)	20	15	20	15	20	15	15	15
Dwell (Minutes)	30	30	30	30	30	30	30	30
Maximum Temp.(°F)	336	342	335	340	333	336	334	339
Weight (oz/ft^2)	[1]	[2]	[2]	[2]	[2]	[2]	[2]	[2]
Light Trans.(%)	[3]	83.2/ 84.6	83.8/ 84.6	84.4/ 85.7	84.1/ 85.7	83.2/ 85.2	83.8/ 86.3	[3]
Haze (%)	[3]	3.3/5.3	4.3/5.1	4.8/6.2	4.9/5.4	2.6/5.9	4.8/5.8	
Date	12-4	12-5	12-8	12-9	12-9	12-10	12-10	12-10

NOTES:
1. Molding size: 16" x 27", Molded to a nominal thickness of 0.094".
2. Molding Size: 16" x 27", Molded to a nominal thickness of 0.313".
3. Light transmission and haze not measured. Molding unsuitable for triangular windows, used for A.R. coating trials.

APPENDIX B

MOLDING CYCLES

TASK I	-	Figures I-1 through I-5
TASK II	-	Figures II-1 through II-20
TASK III	-	Figures III-1 through III-34
TASK IV	-	Figures IV-1 through IV-10
TASK VI	-	Figures VI-1 through VI-19

FIGURE I-1

TRANSPARENT POLYIMIDE FILM
MOLDING CHILLED
FILM 6 MILS THICK
TEMP. (°F)
TIME (MINUTES)

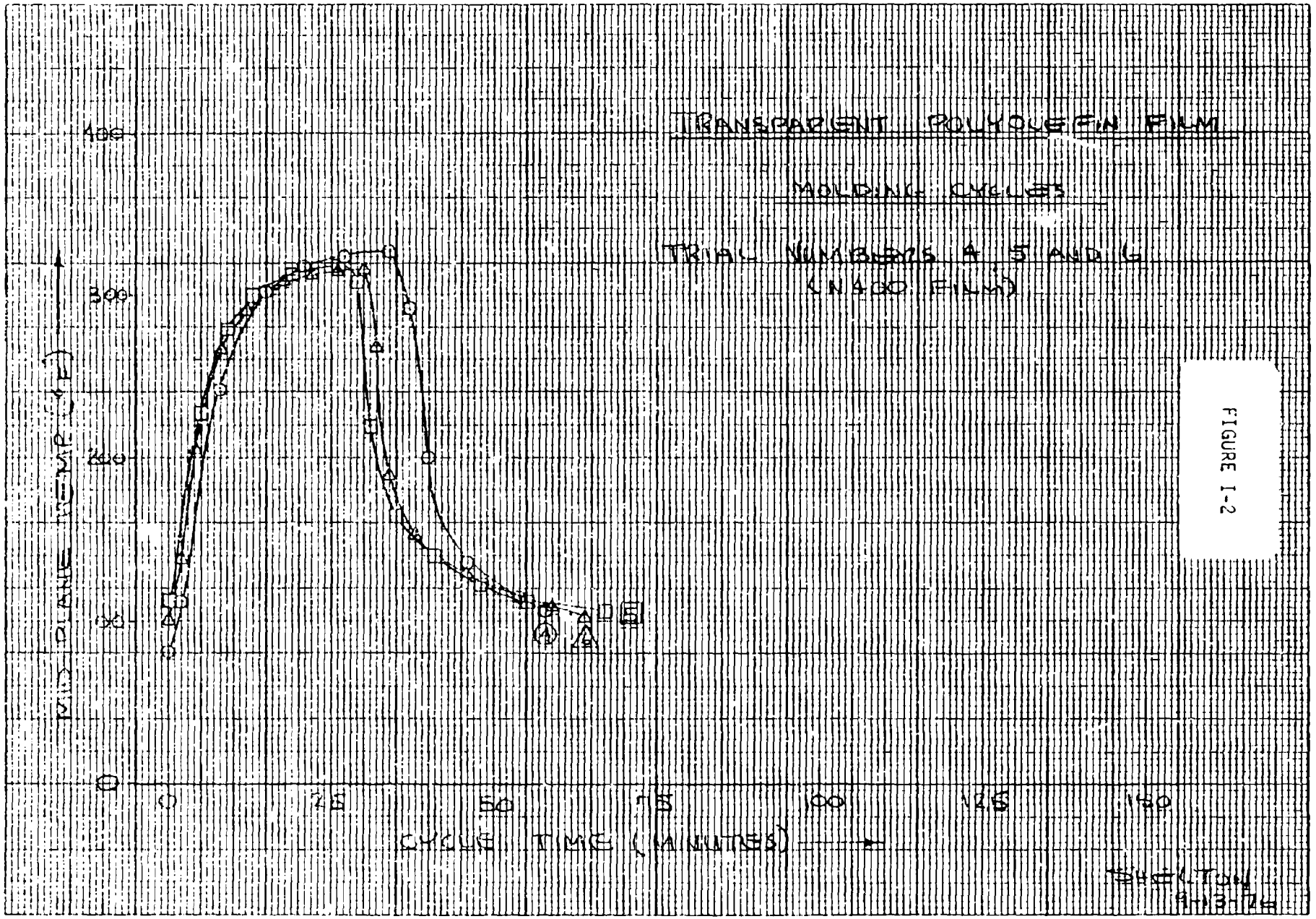


FIGURE I-2

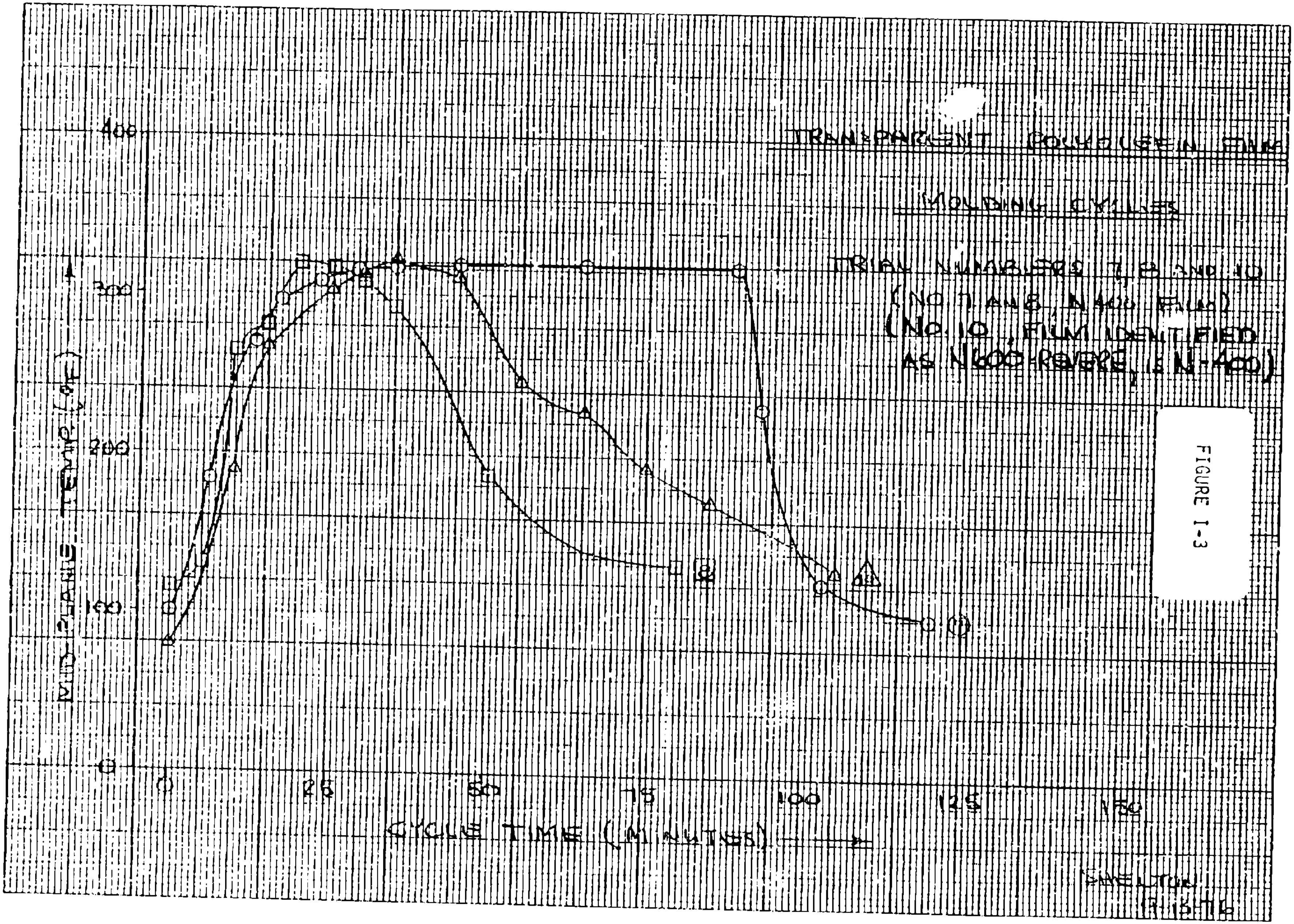


FIGURE I-3

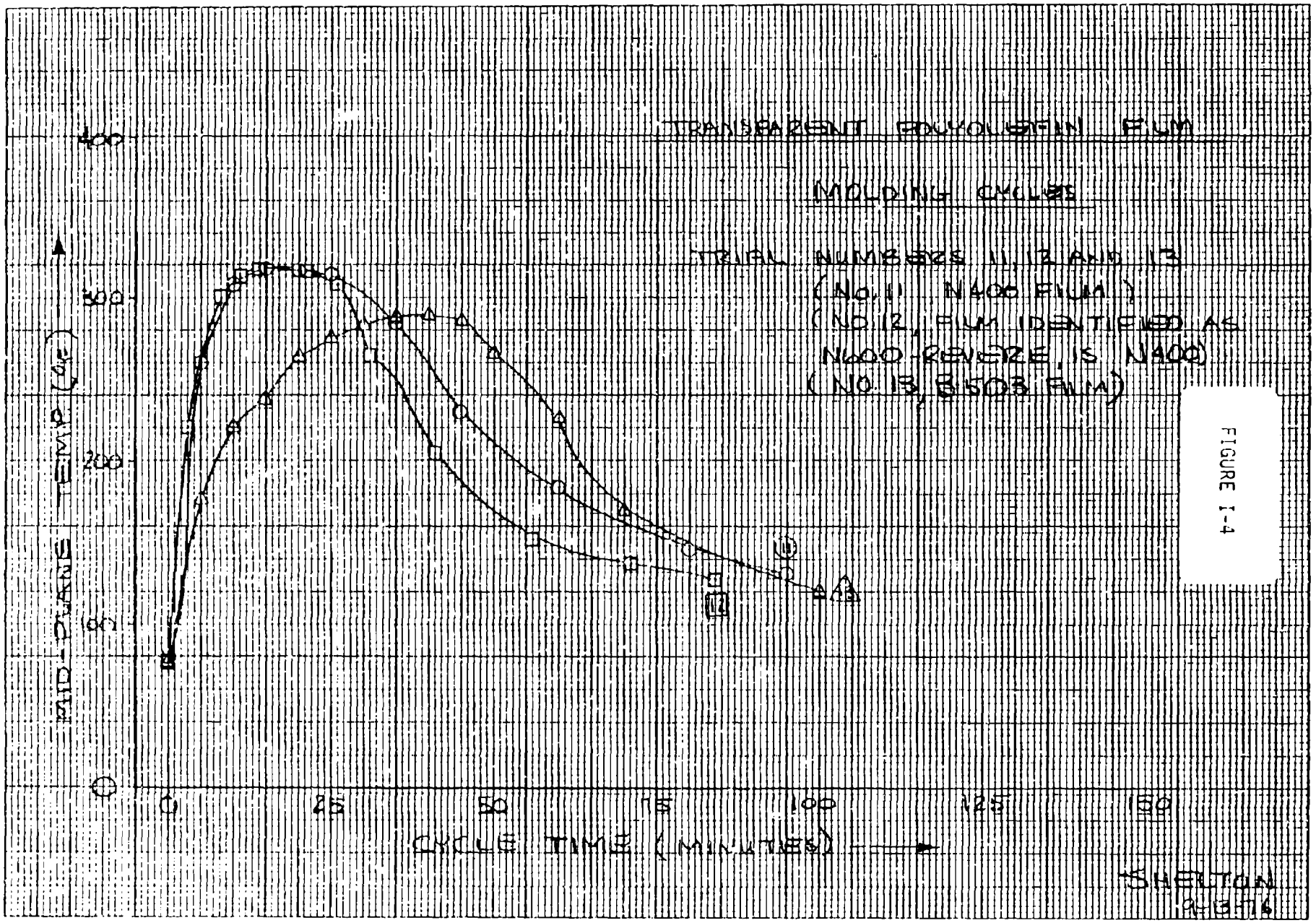


FIGURE I-5

FIGURE II-1

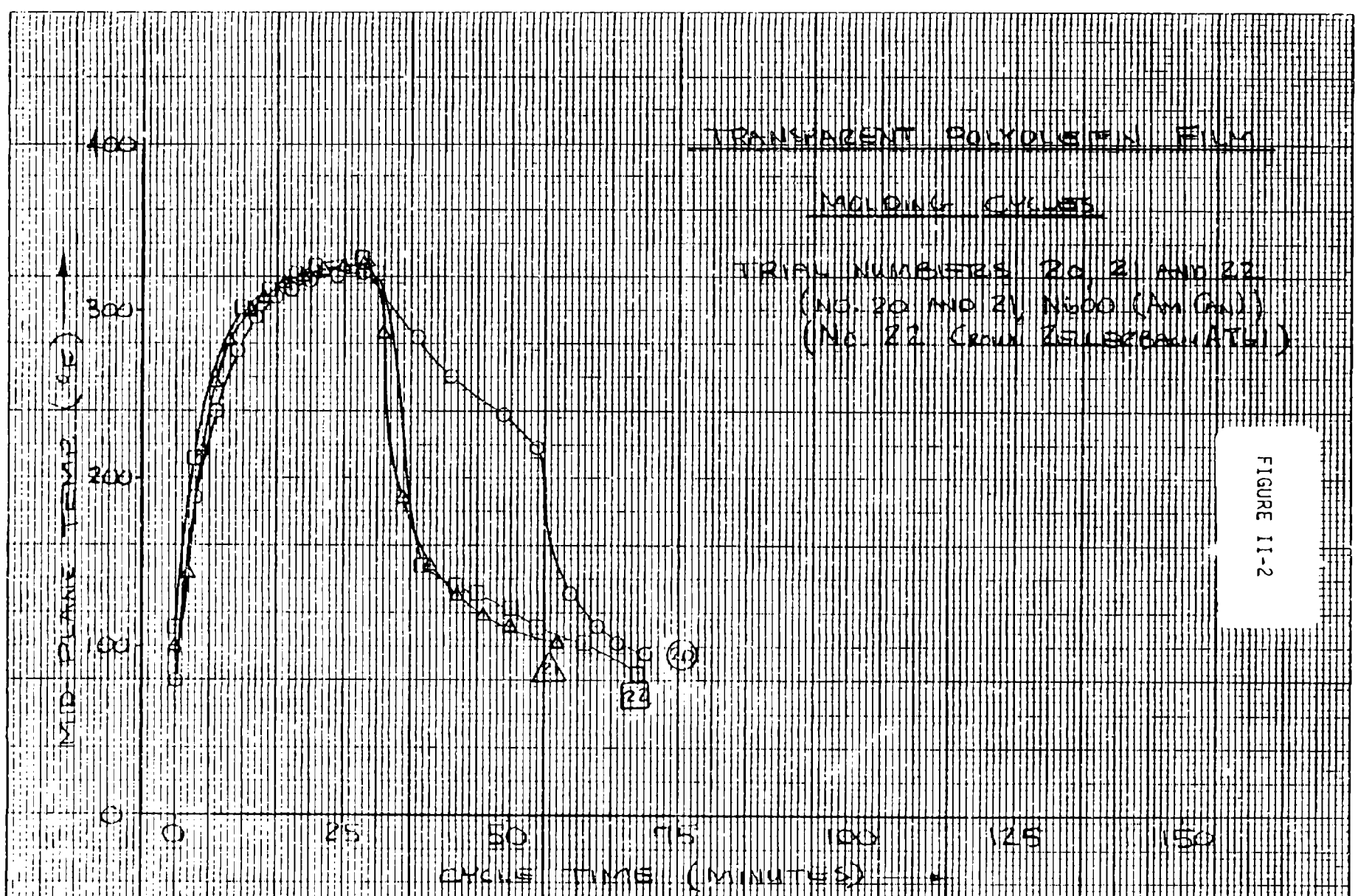


FIGURE II-2

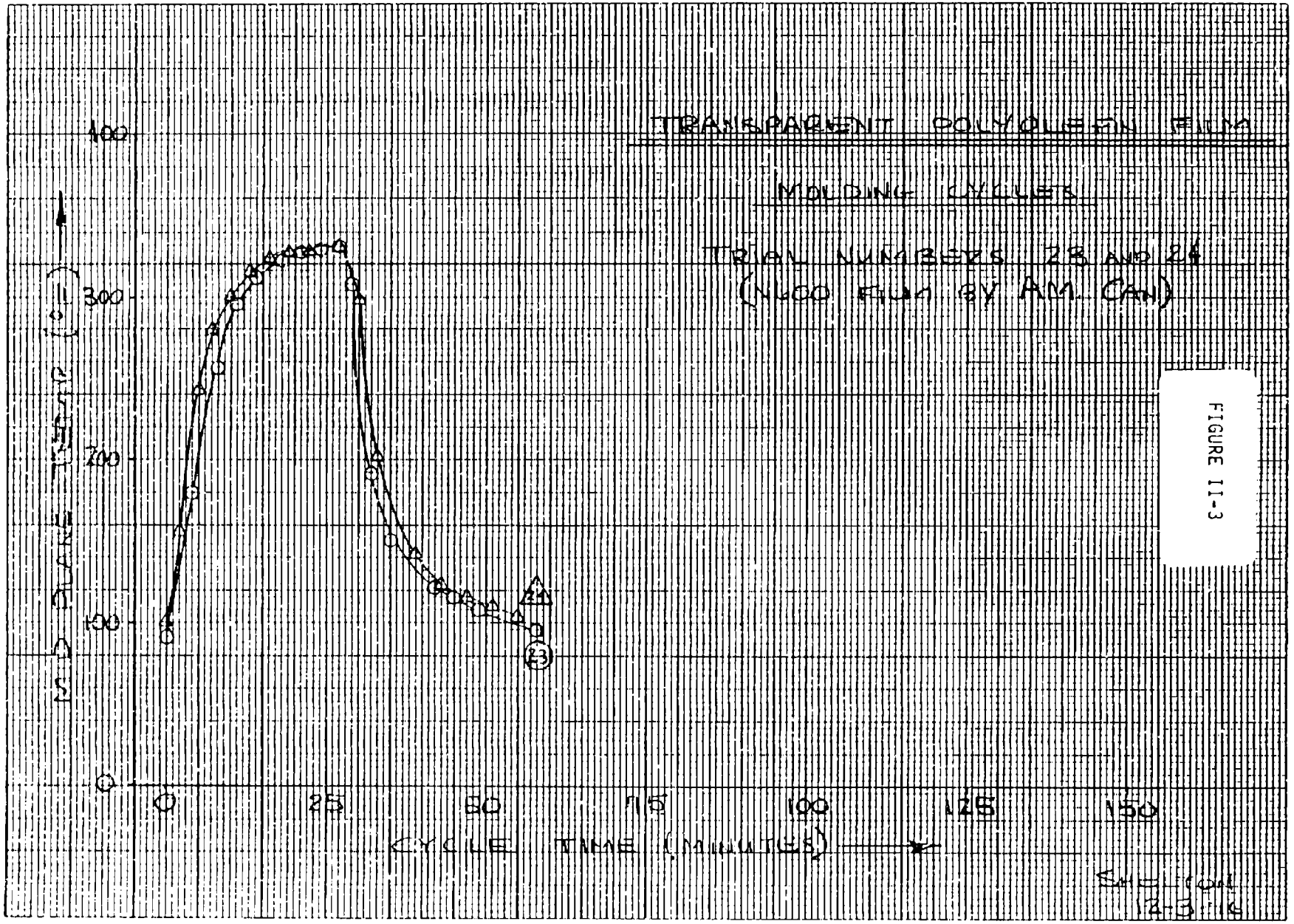


FIGURE II-3

FIGURE II-4

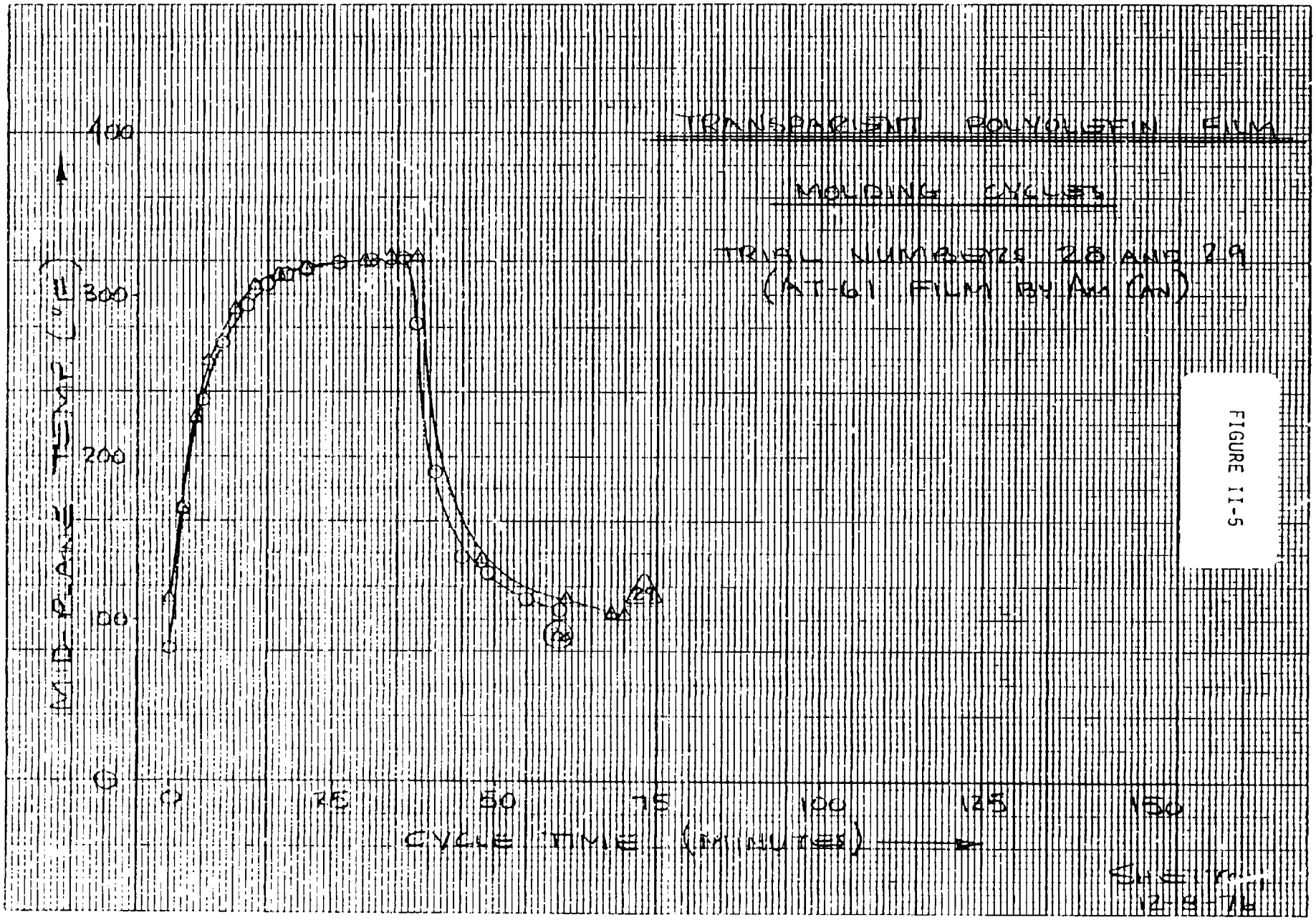


FIGURE II-5

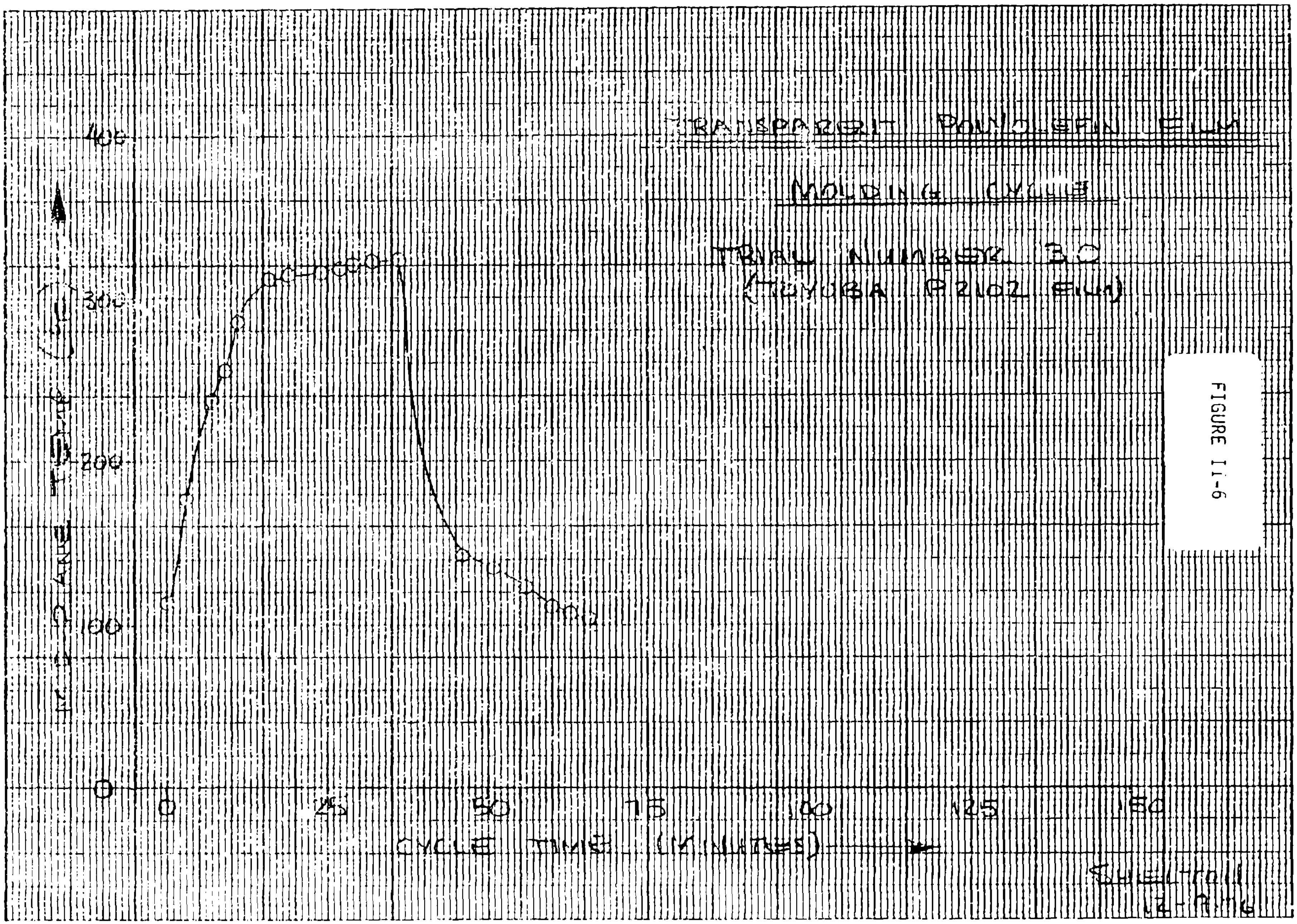


FIGURE II-6

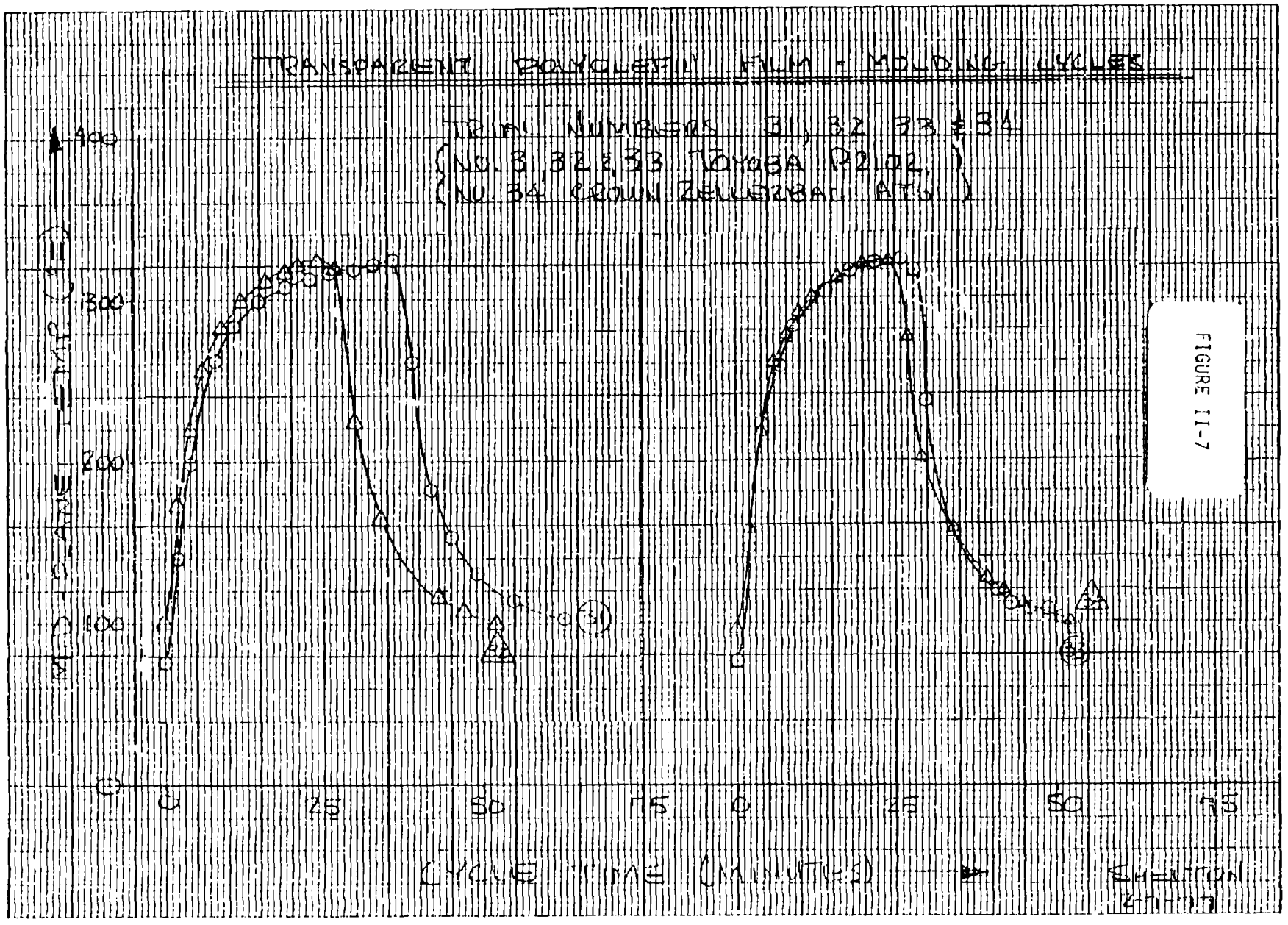

TRANSPARENT POLYSTYRENE FILM - MOLDING CYCLES
RUN NUMBERS 31, 32, 33, & 34
(NO. 31, 32, & 33 TOMSA P202)
(NO. 34 CROWN ZELLSTRAT)
400
300
200
100
0
25
50
75
0
25
50
CYCLE TIME (MINUTES)

FIGURE II-7

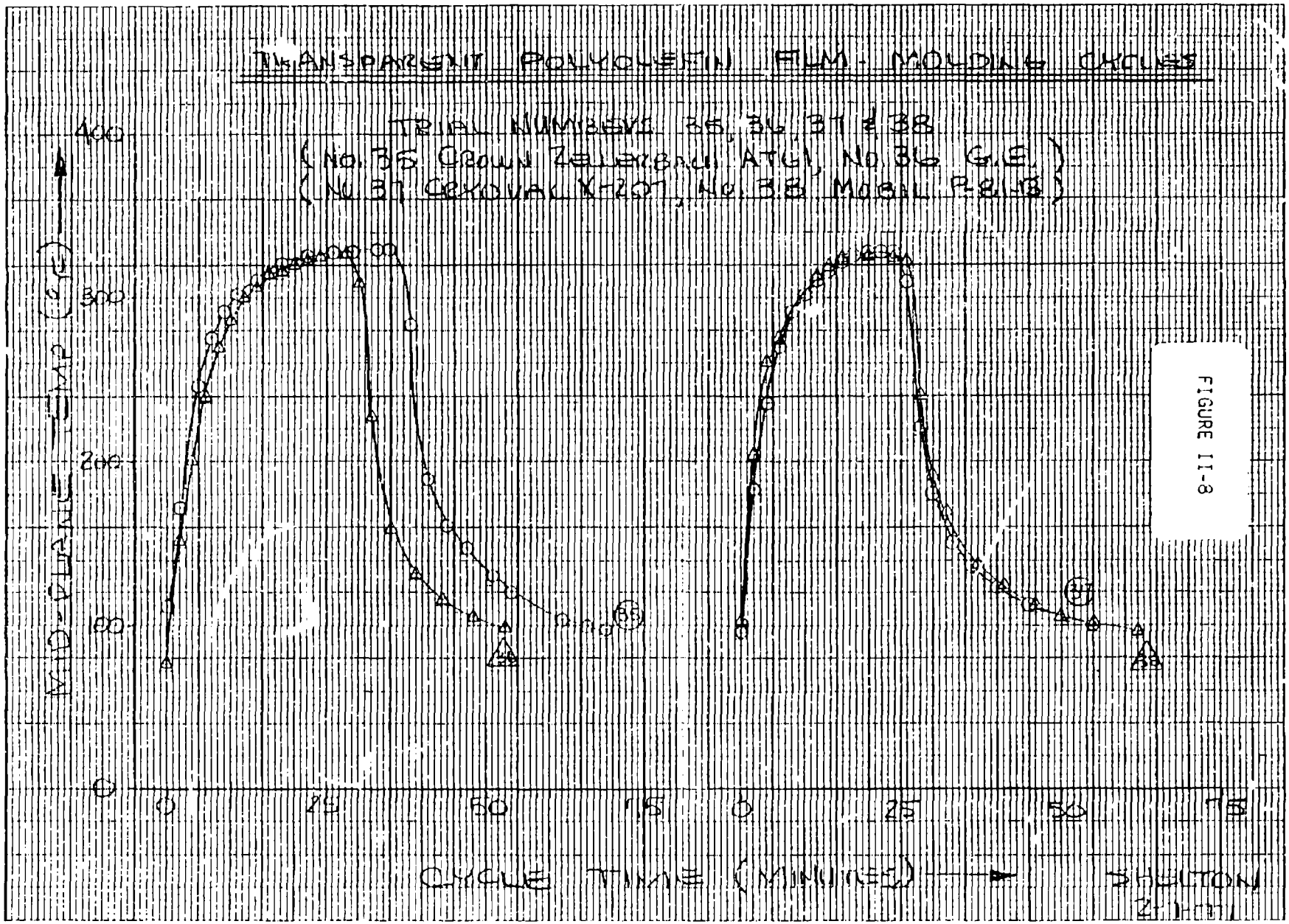

TRANSPARENT POLYCARBONATE FILM - MOLDING CYCLES
TRIAL NUMBERS 35, 34, 37 & 38
(No. 35 Crown Zellerbach ATC1, No. 36 G.E.
No. 37 General K-207, No. 38 Mobay P-2-8)
400
300
200
100
0
0
25
50
75
0
25
50
75
CYCLE TIME (MINUTES)
INJECTION

FIGURE II-8

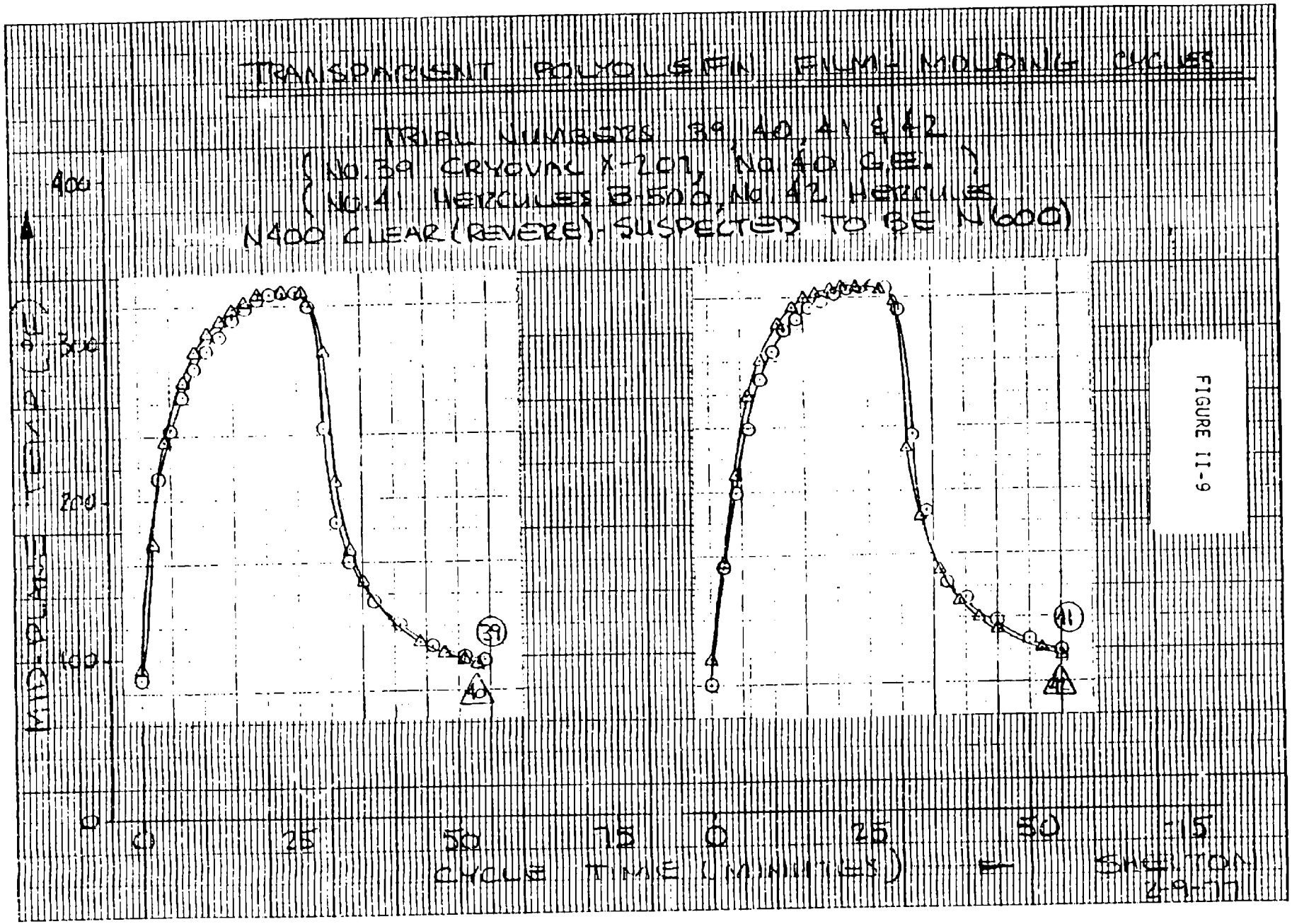

TRANSPARENT POLYOLEFIN FILM - MOLDING CYCLES
TRIAL NUMBERS 39, 40, 41 & 42
(No. 39 CRYOVAC X-210, No. 40 CLEAR
No. 41 HERCULES B-500, No. 42 HERCULES
N400 CLEAR (REVERE) SUSPECTED TO BE N600)
400
200
0
0
25
50
75
0
25
30
39
40
41
42
CYCLE TIME (MINUTES)
CHART NO. 2-9-70

FIGURE II-9

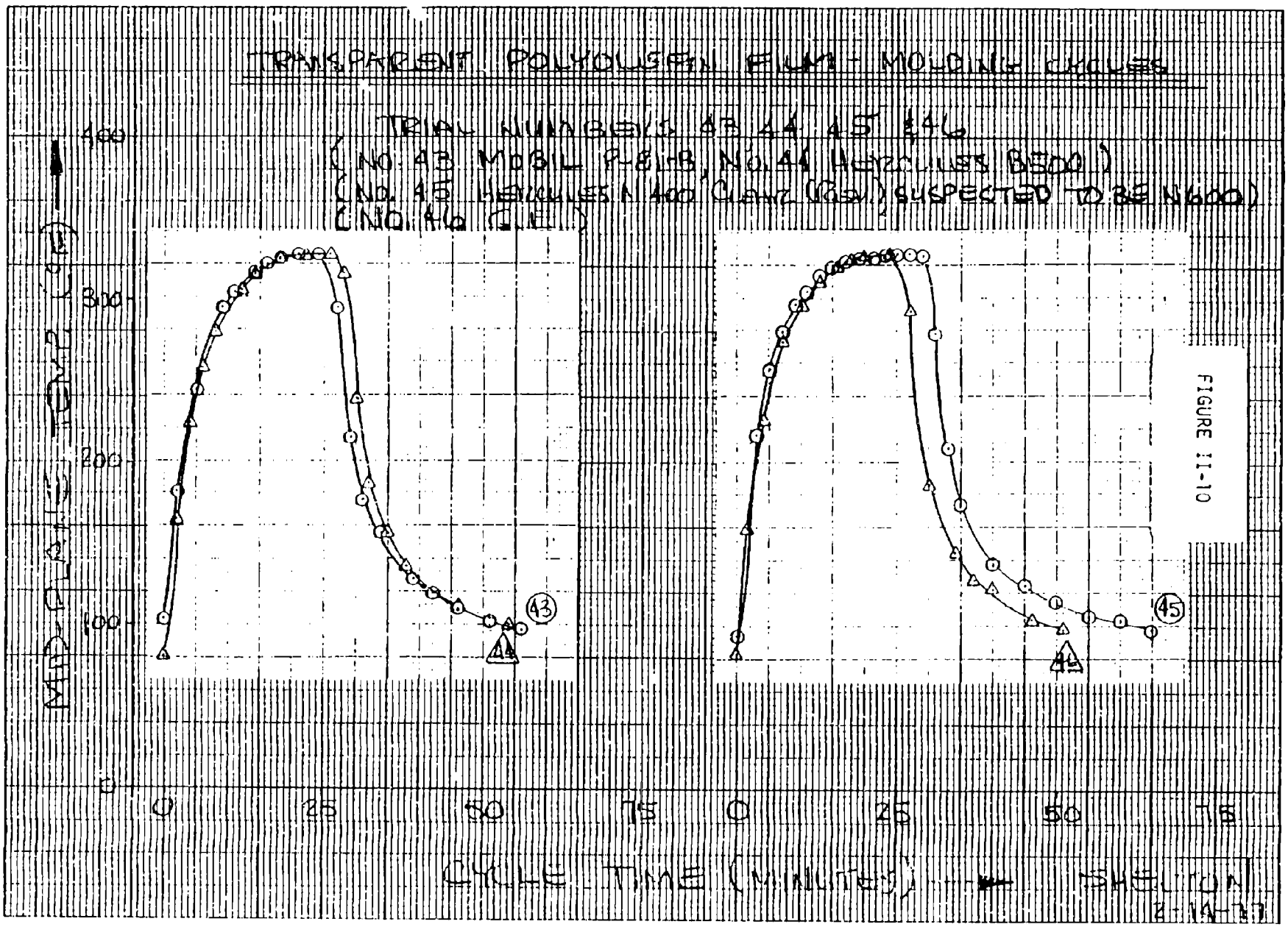


FIGURE II-10

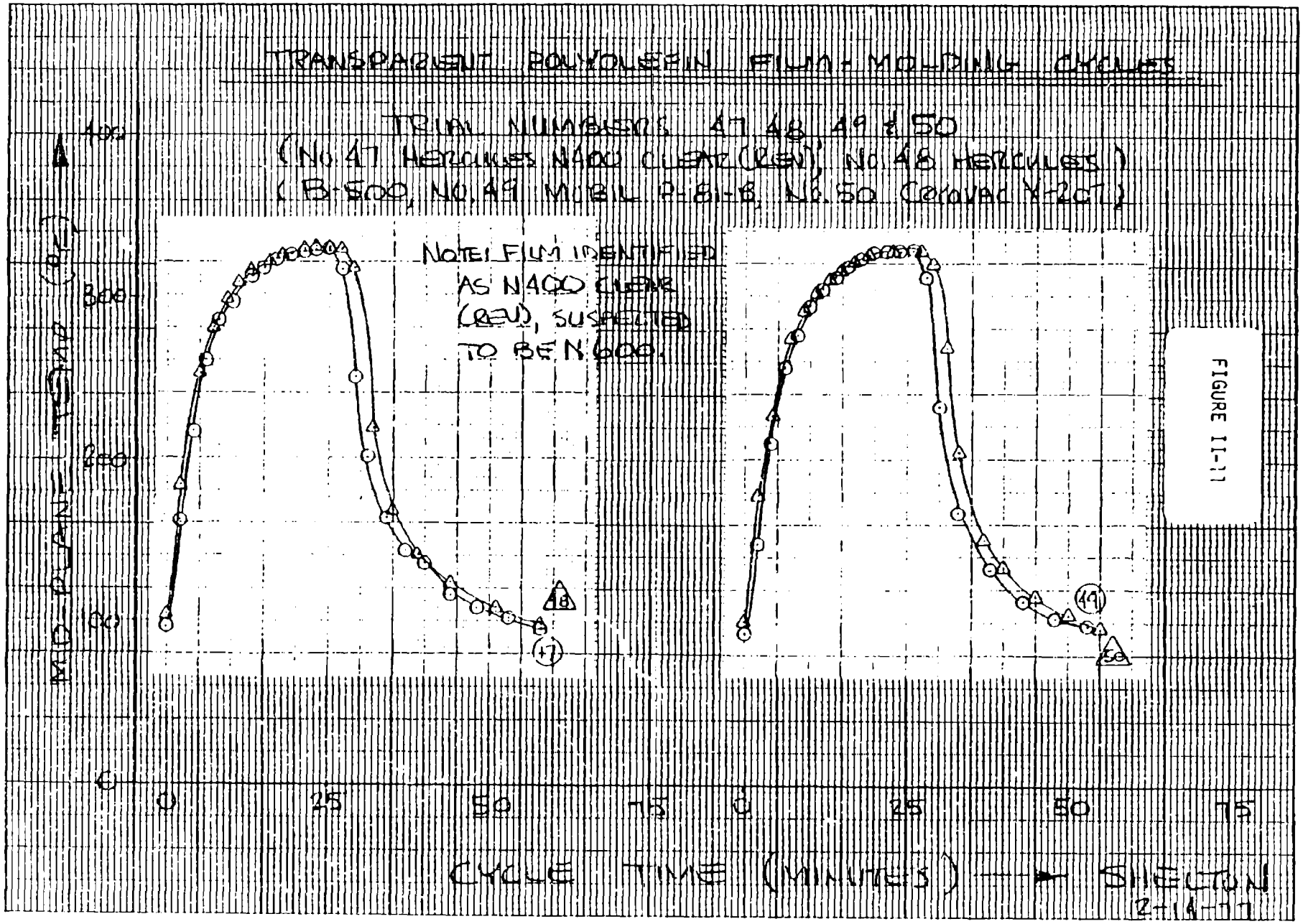


FIGURE II-11

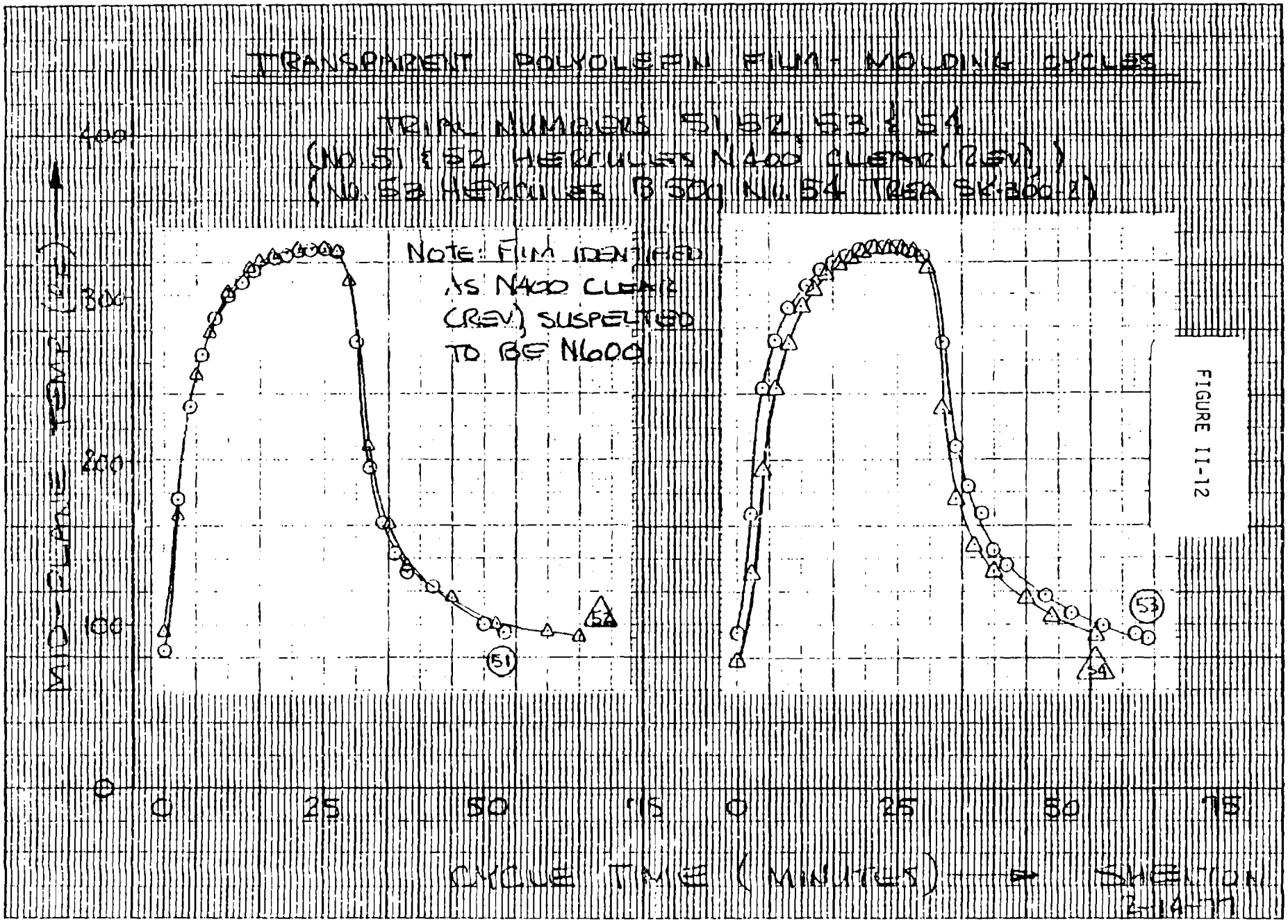


FIGURE II-12

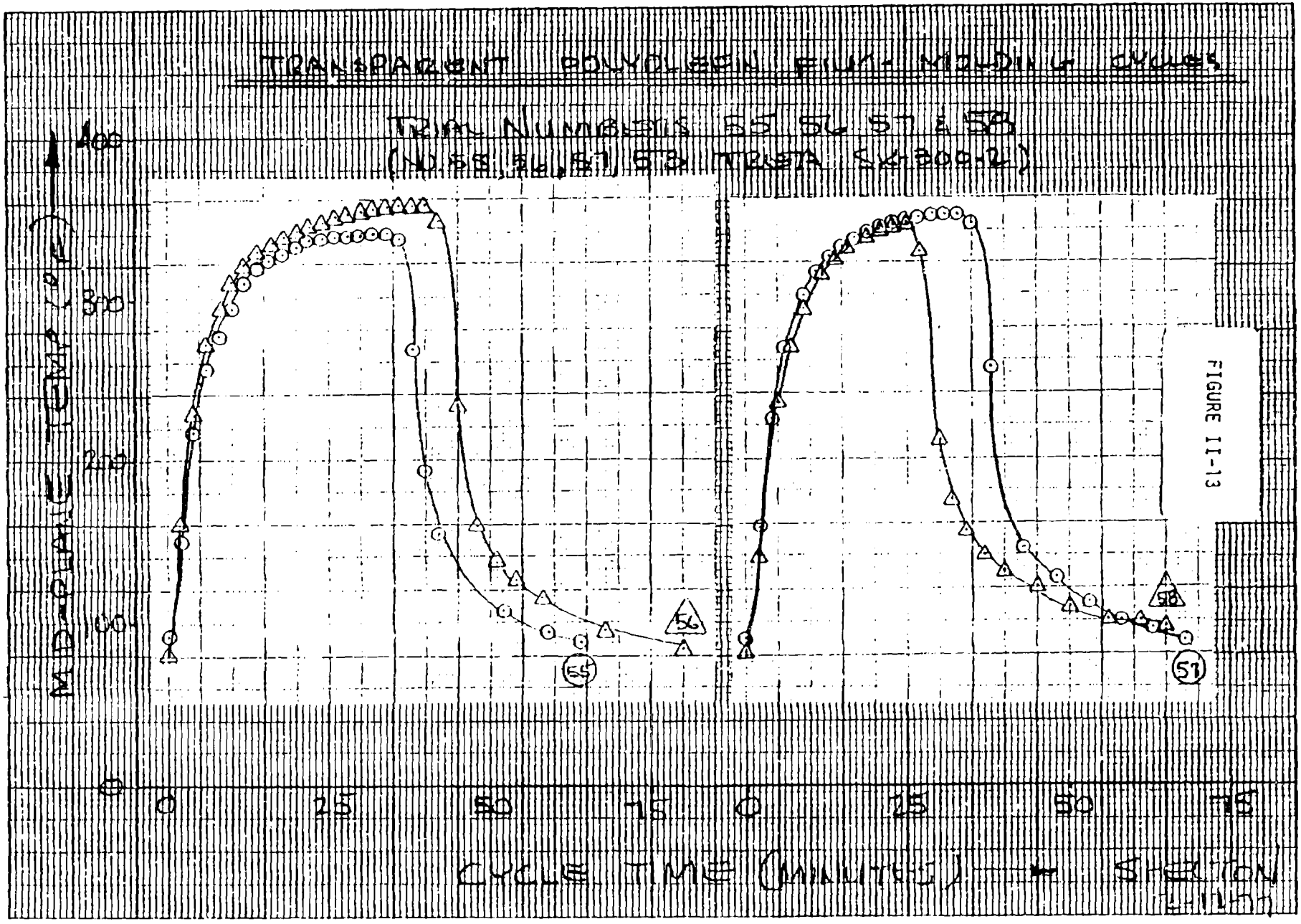


FIGURE II-13

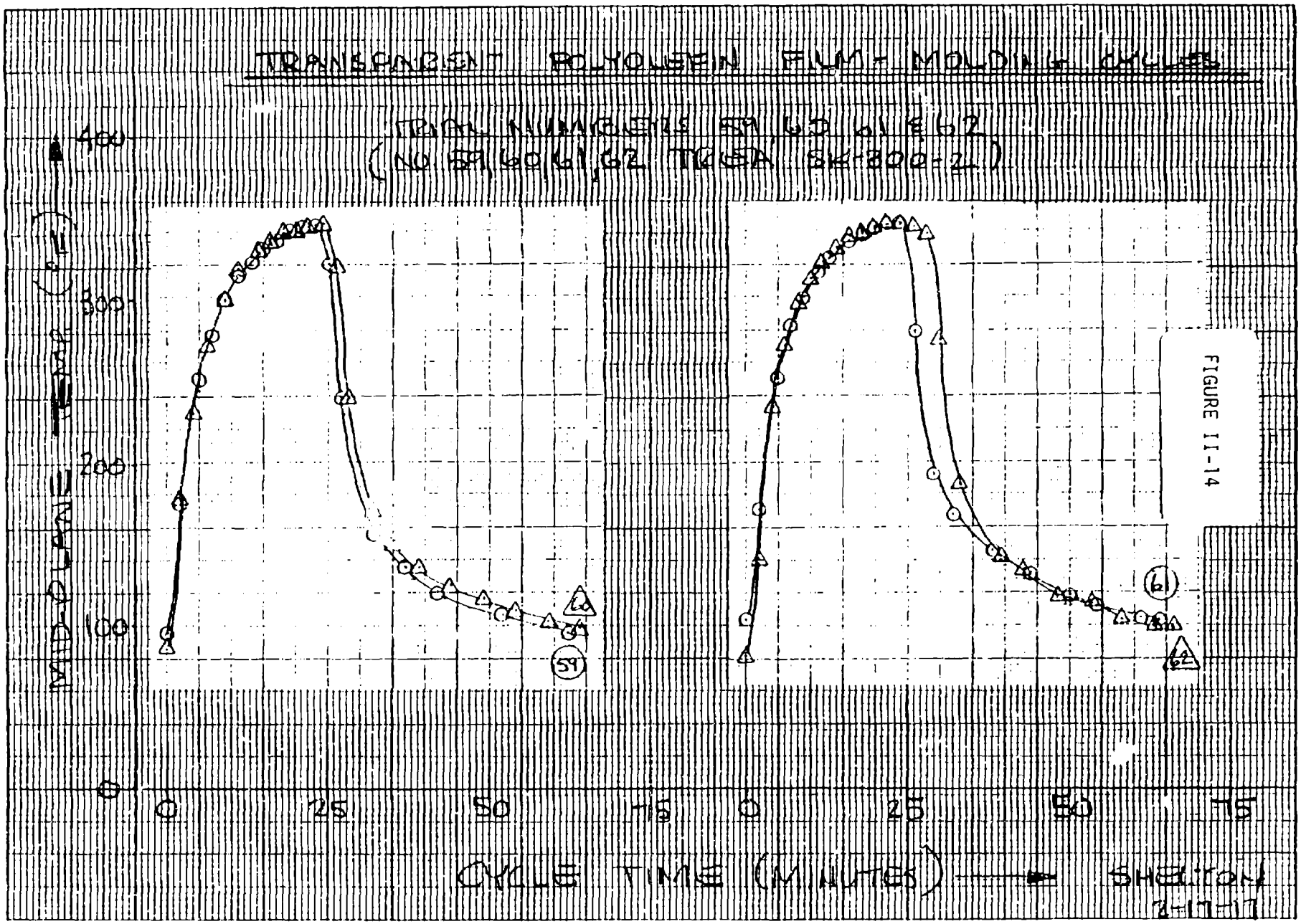
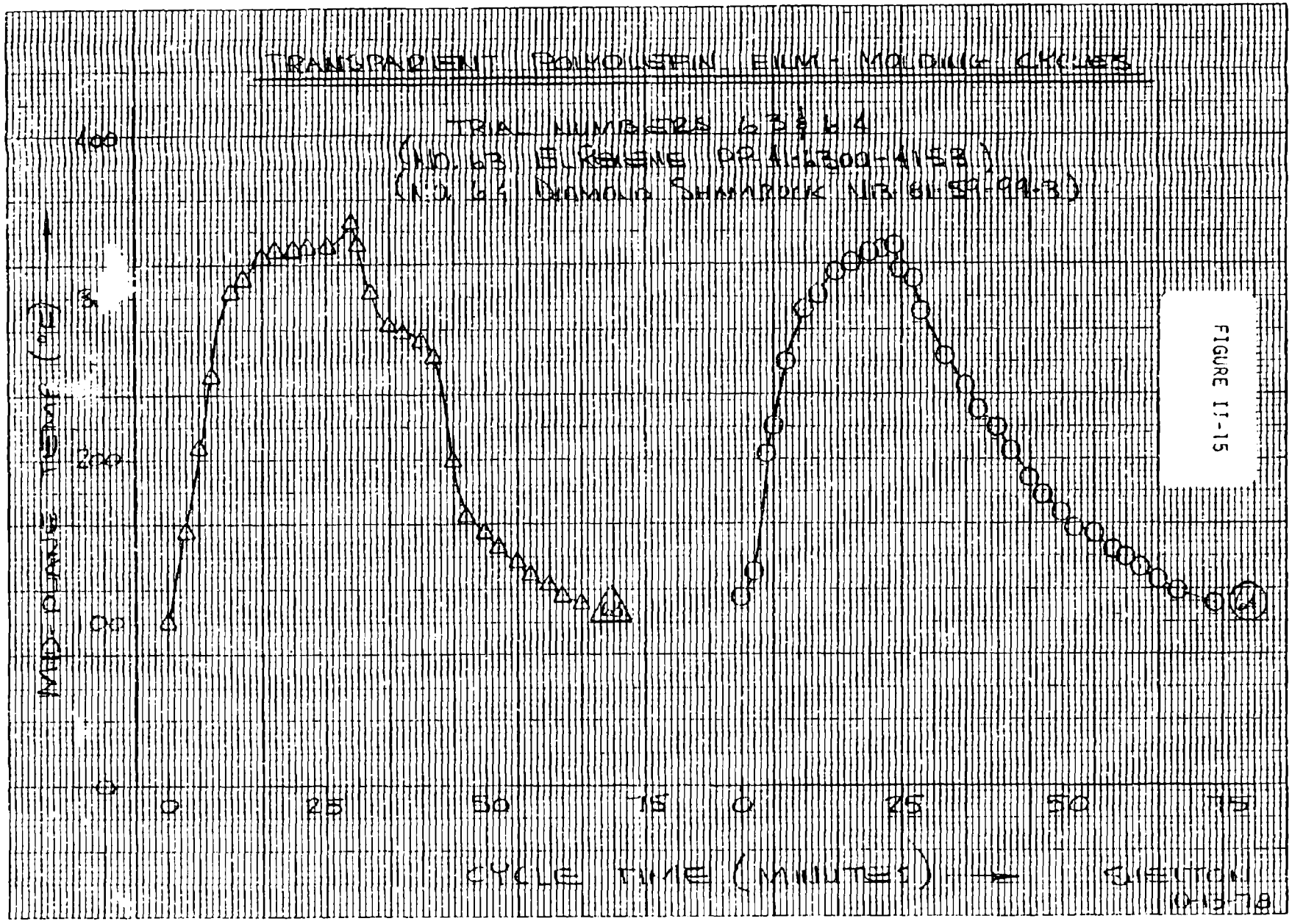
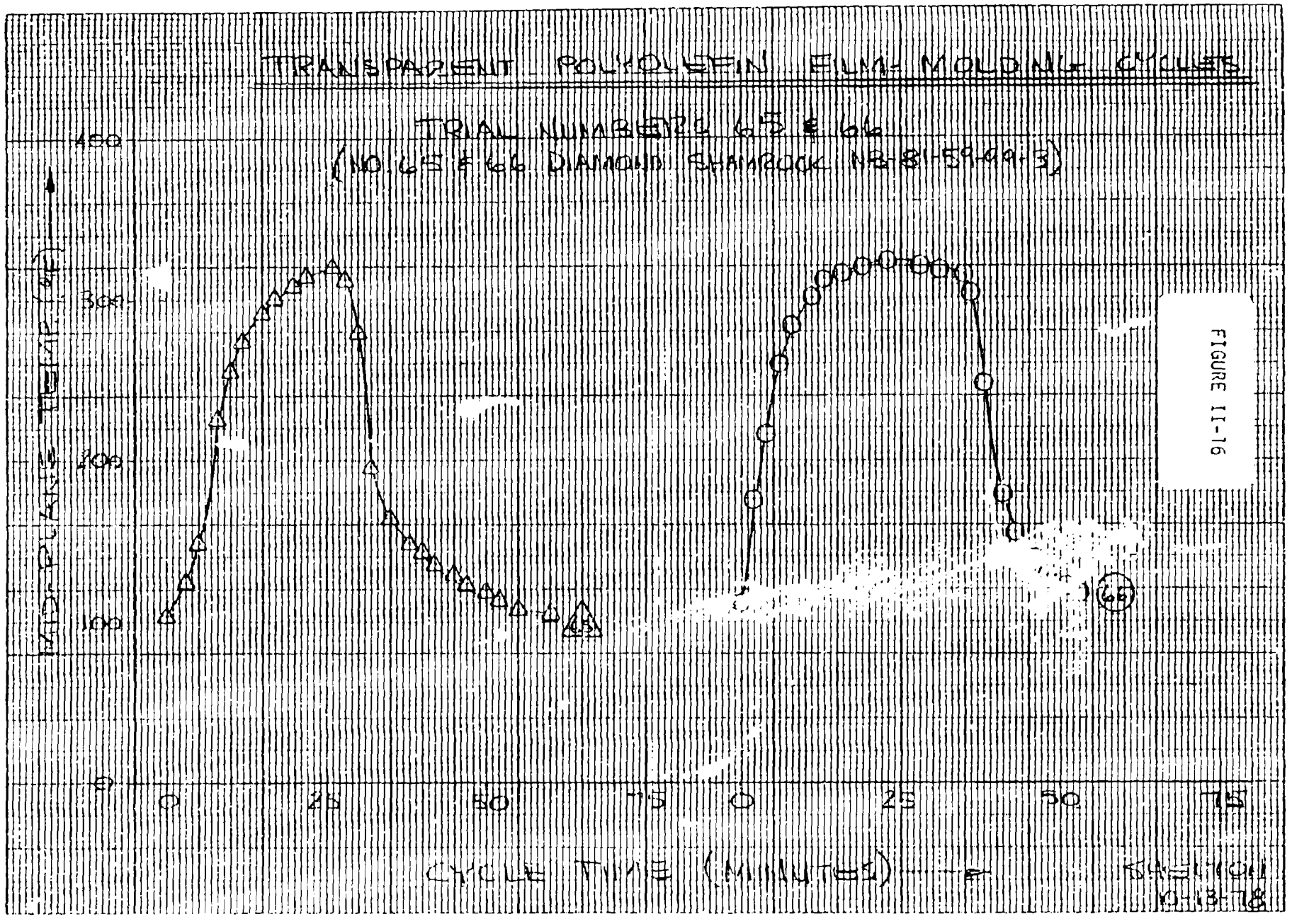


FIGURE II-14





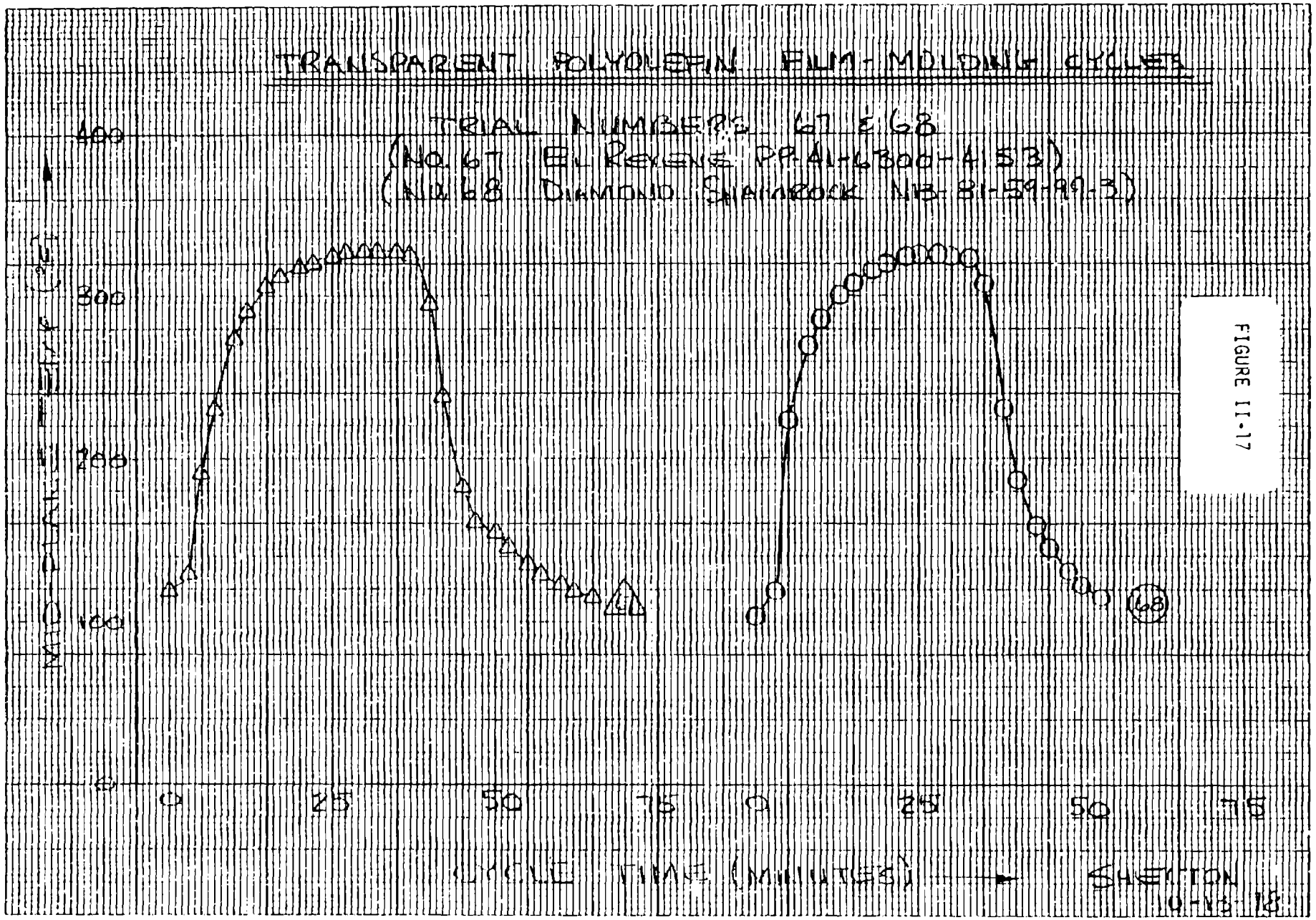
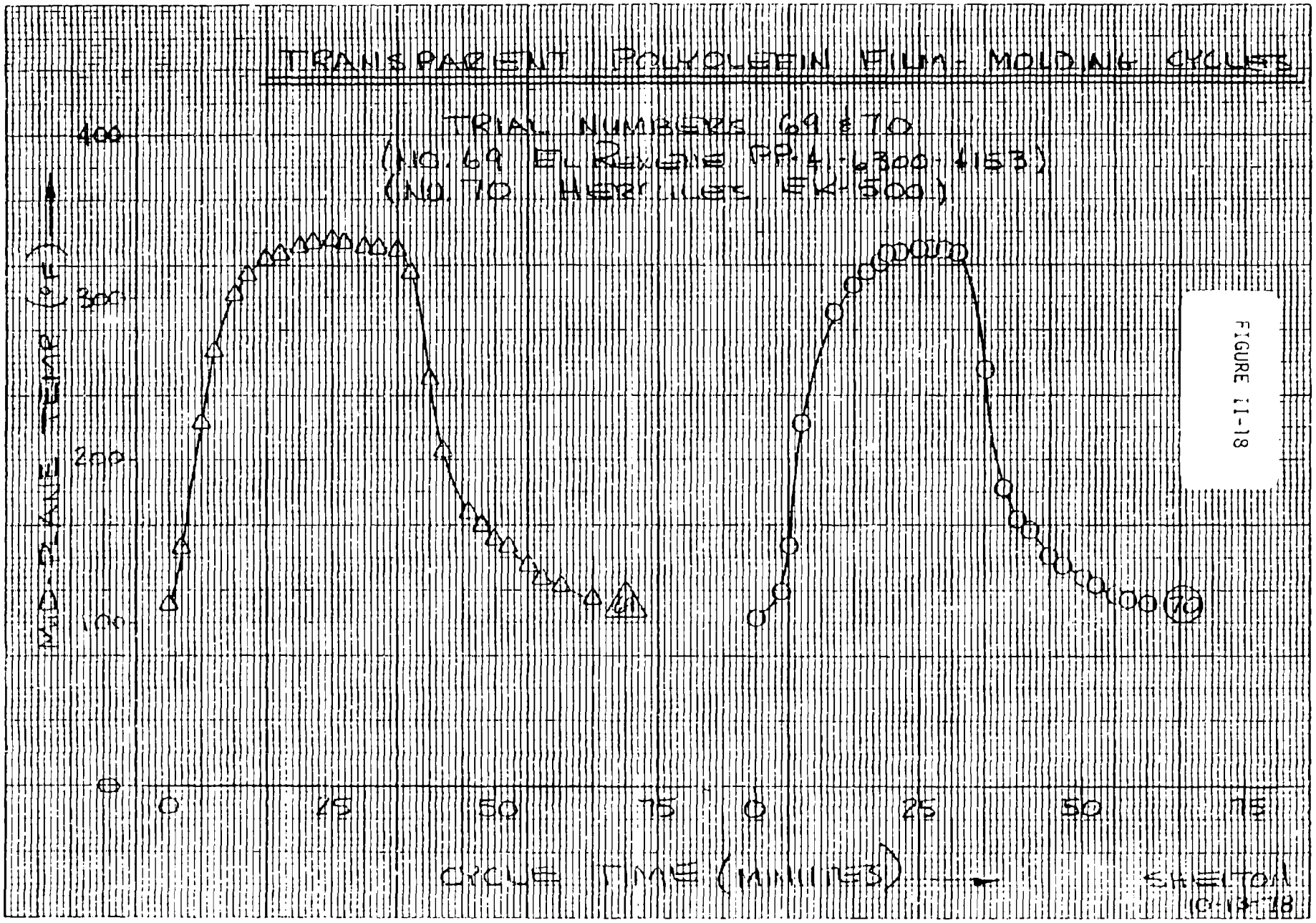


FIGURE II-17



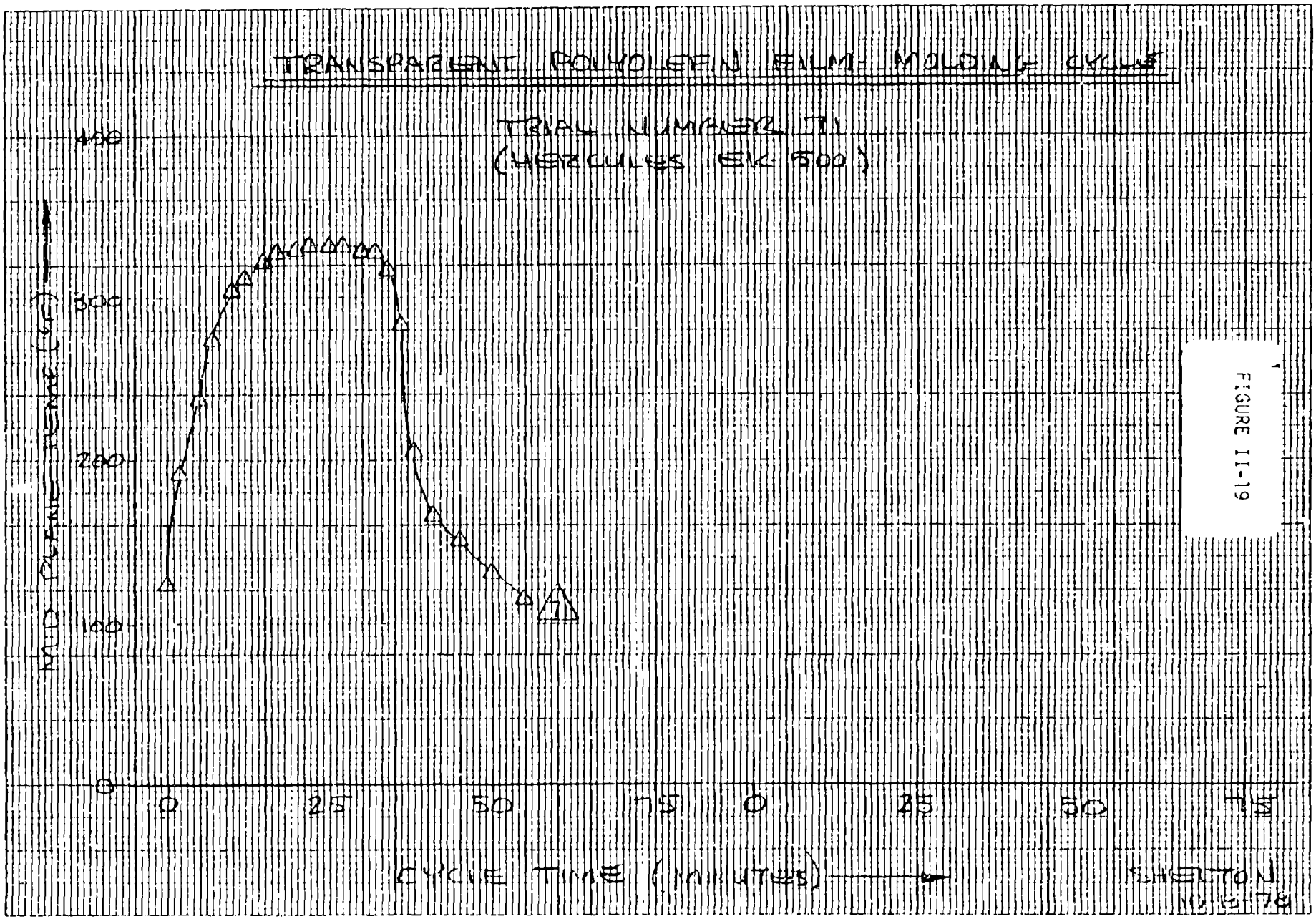


FIGURE II-19

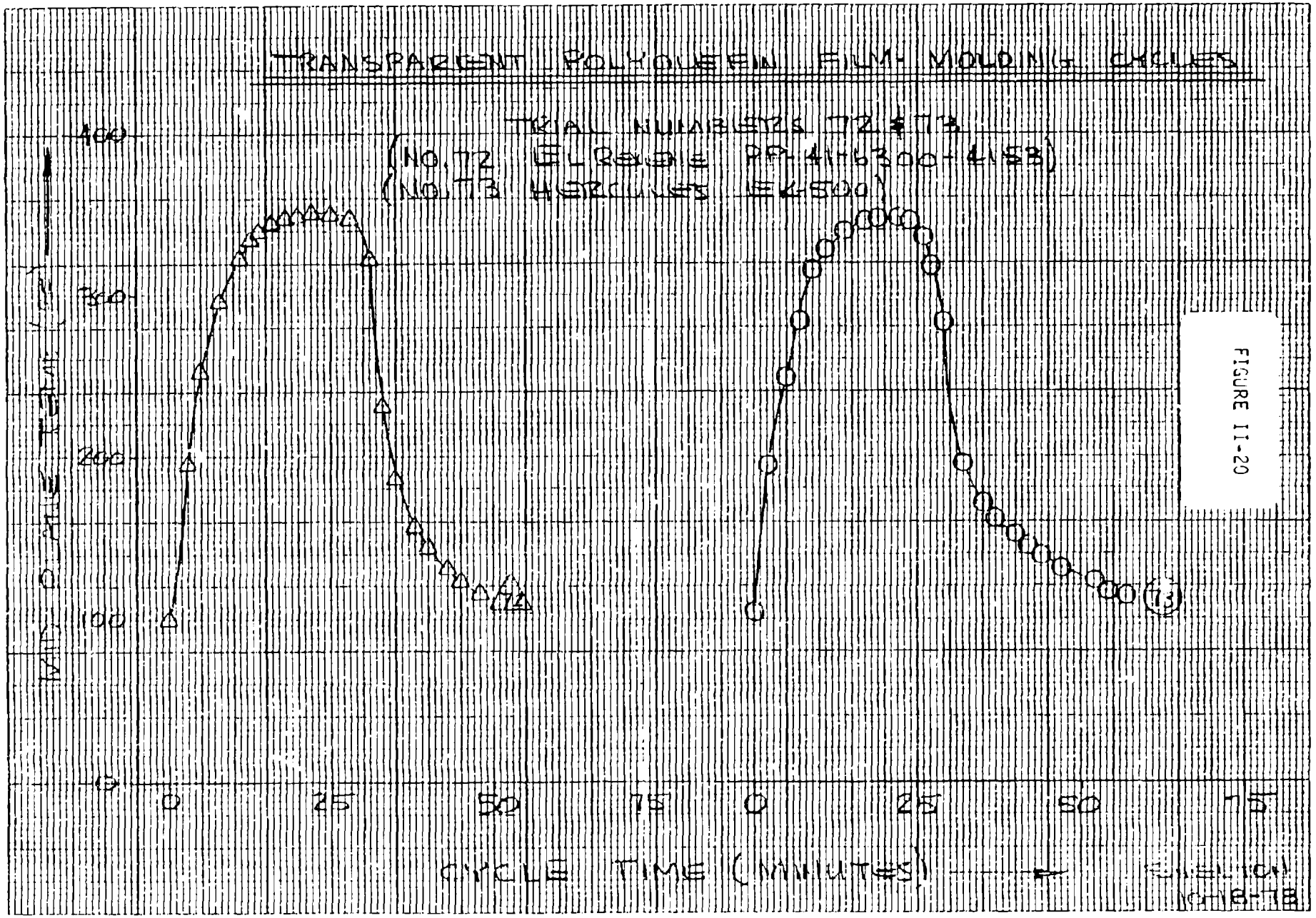


FIGURE II-20

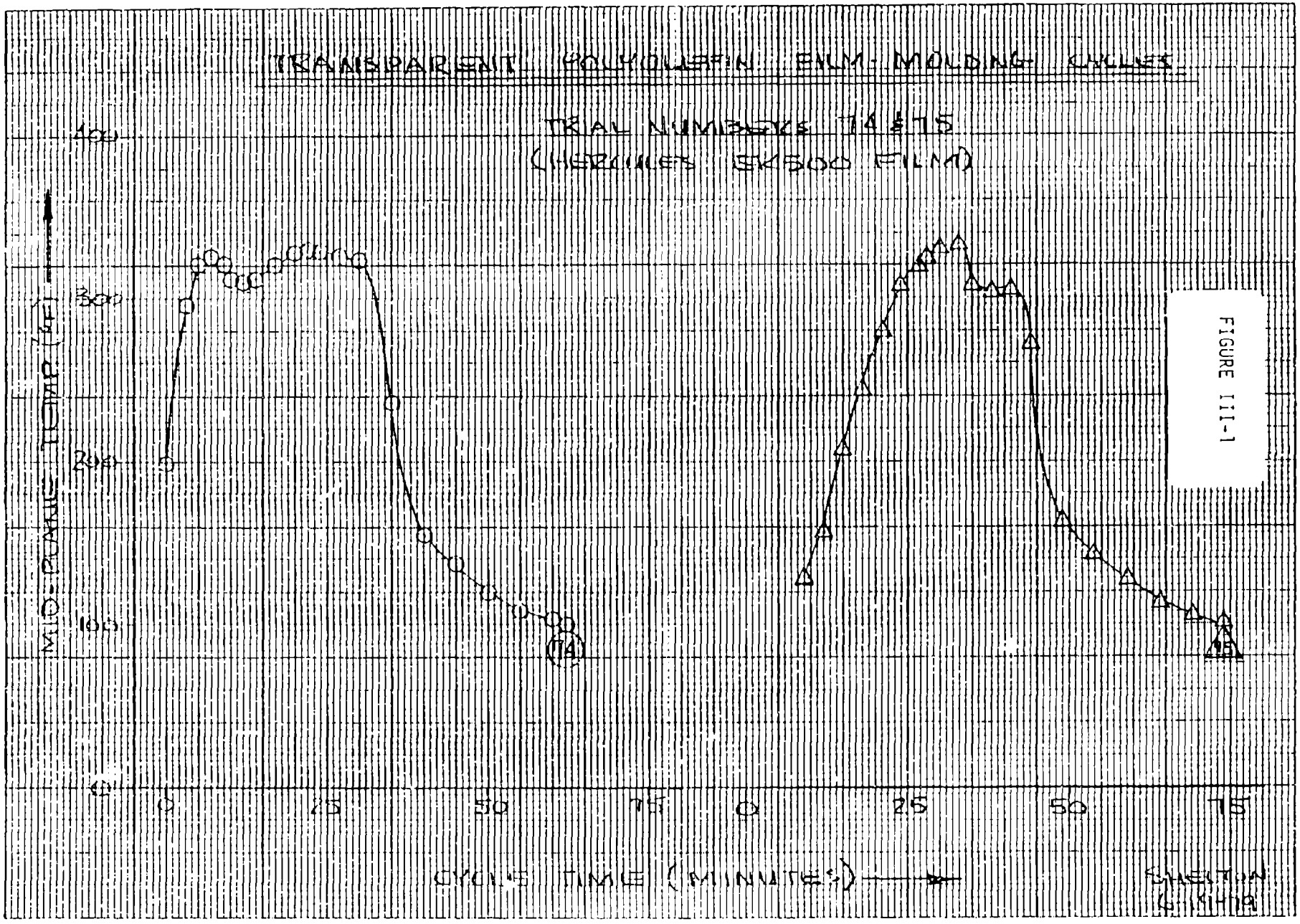


FIGURE III-1

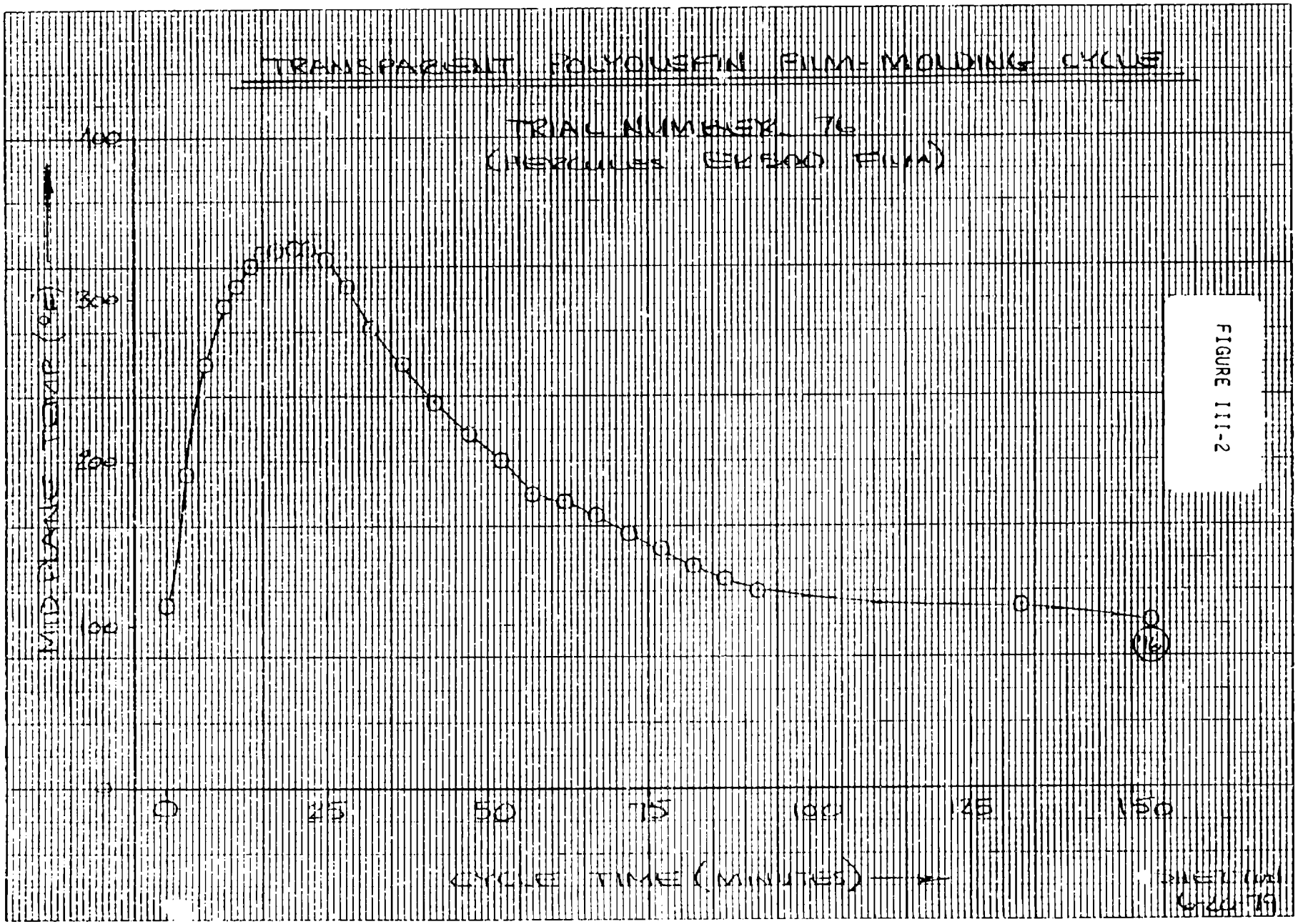


FIGURE III-2

FIGURE III-3

TRANSPARENT
POLYCARBONATE MOLDING
MID PLANE TEMP (°F)
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
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51
52
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79
80
81
82
83
84
85
86
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88
89
90
91
92
93
94
95
96
97
98
99
100

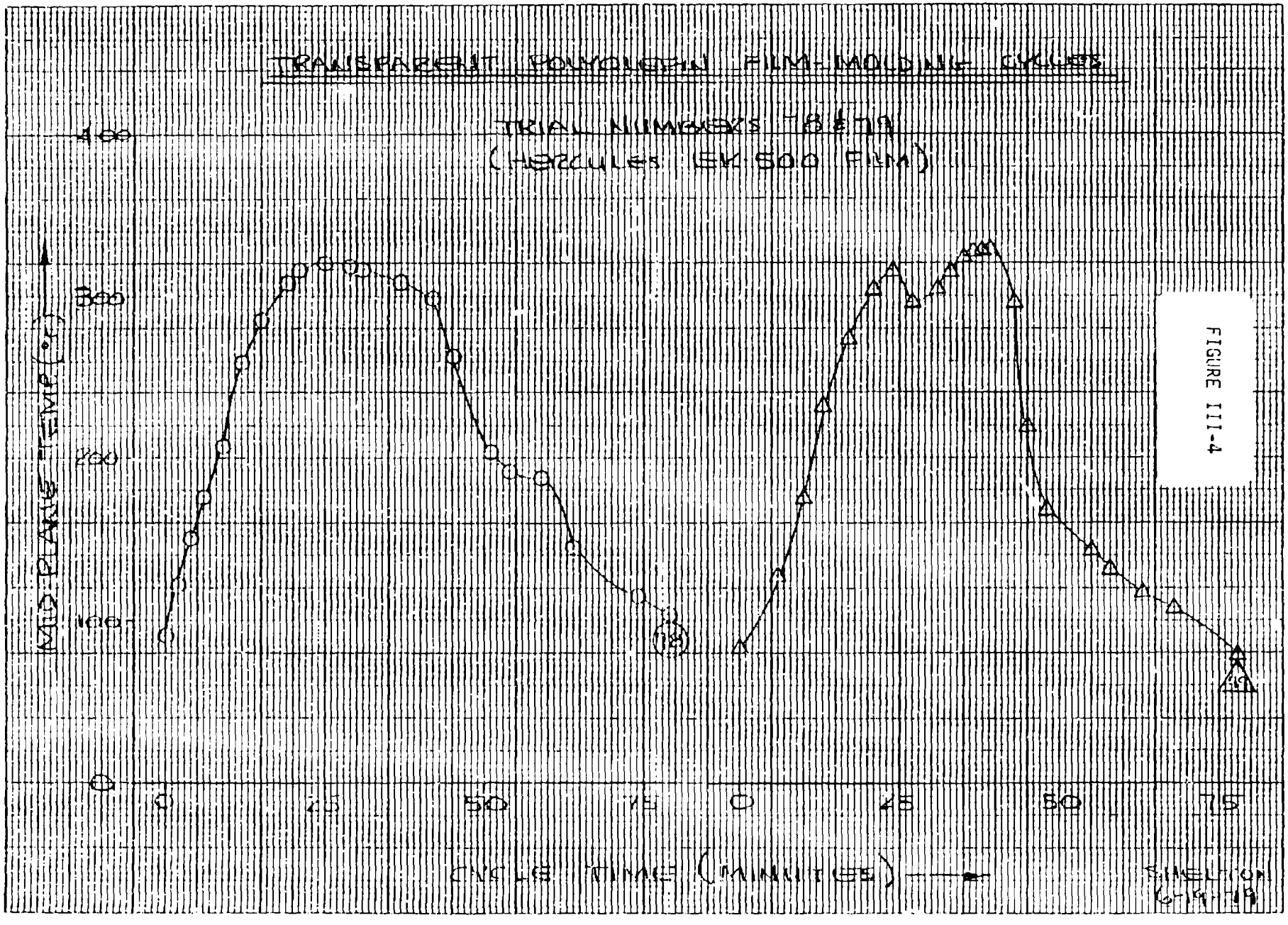


FIGURE III-4

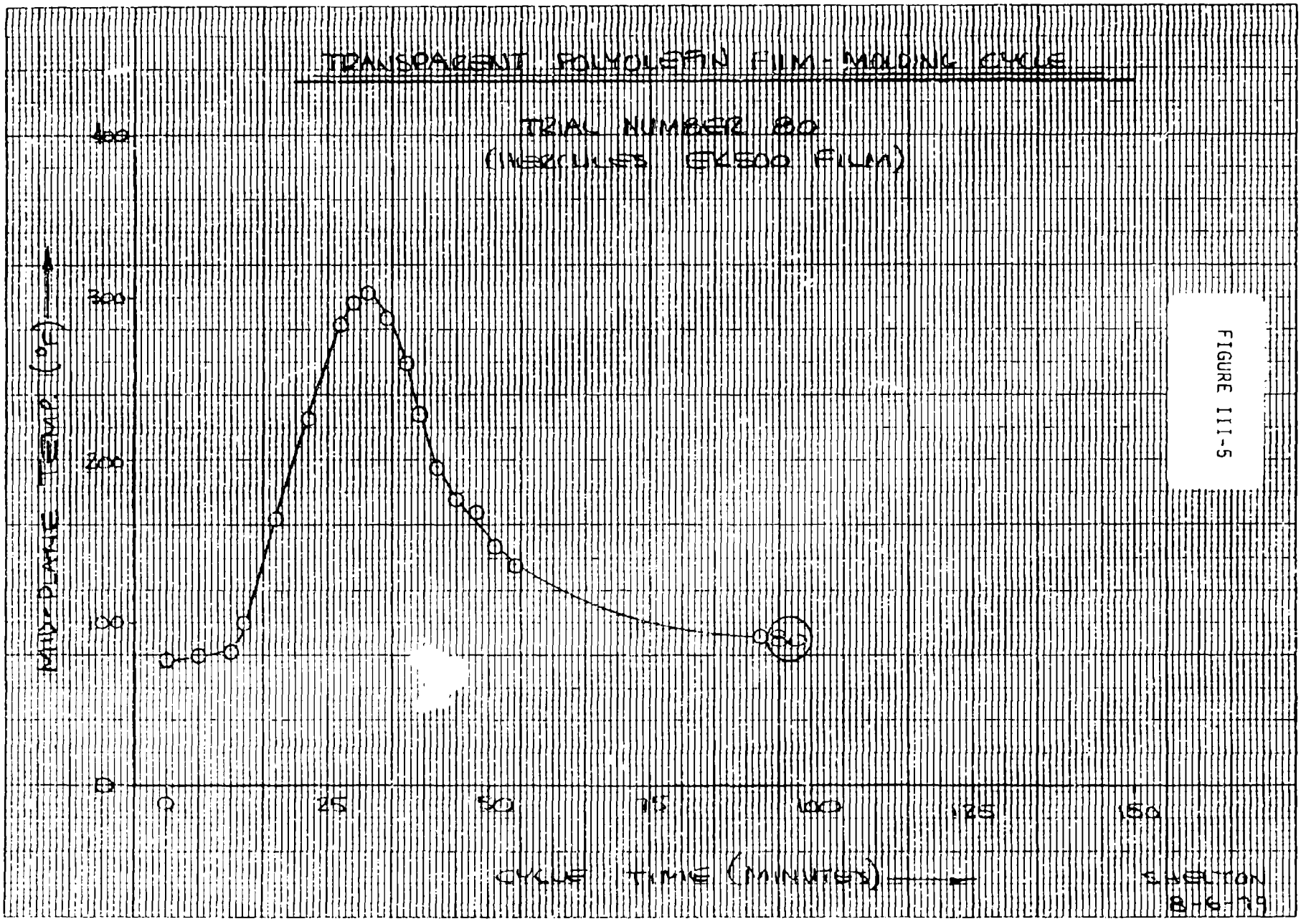


FIGURE III-5

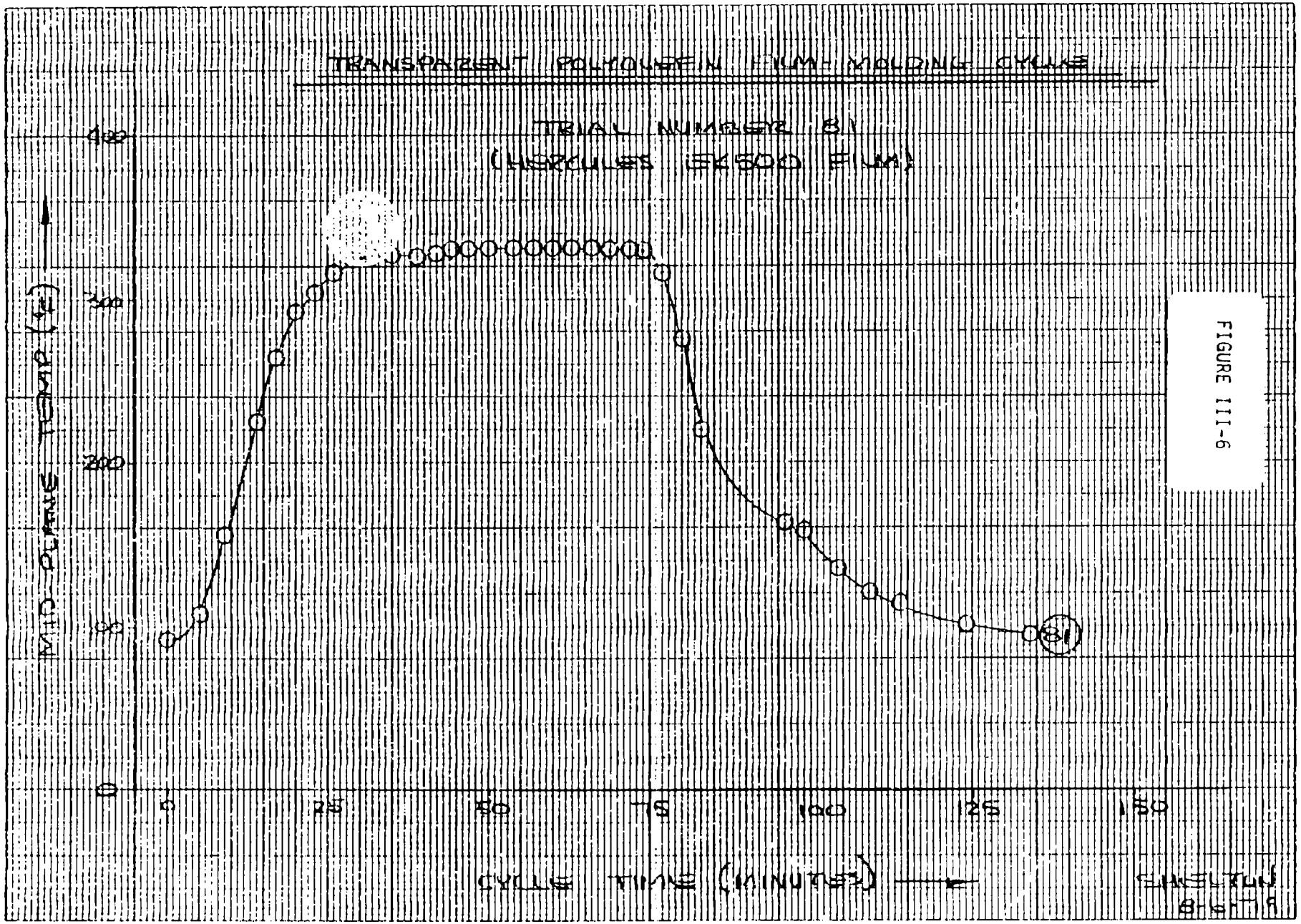


FIGURE III-6

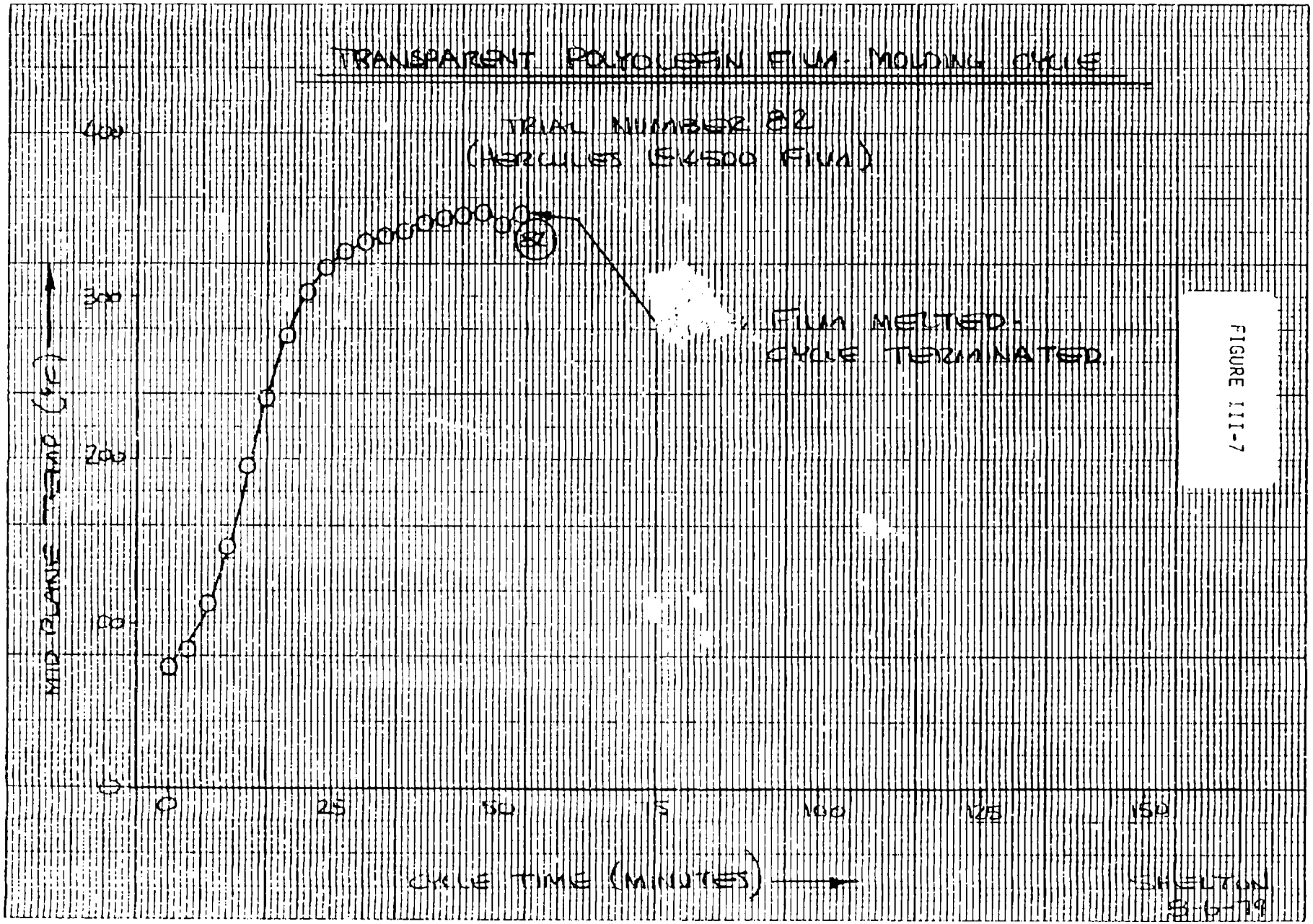


FIGURE III-7

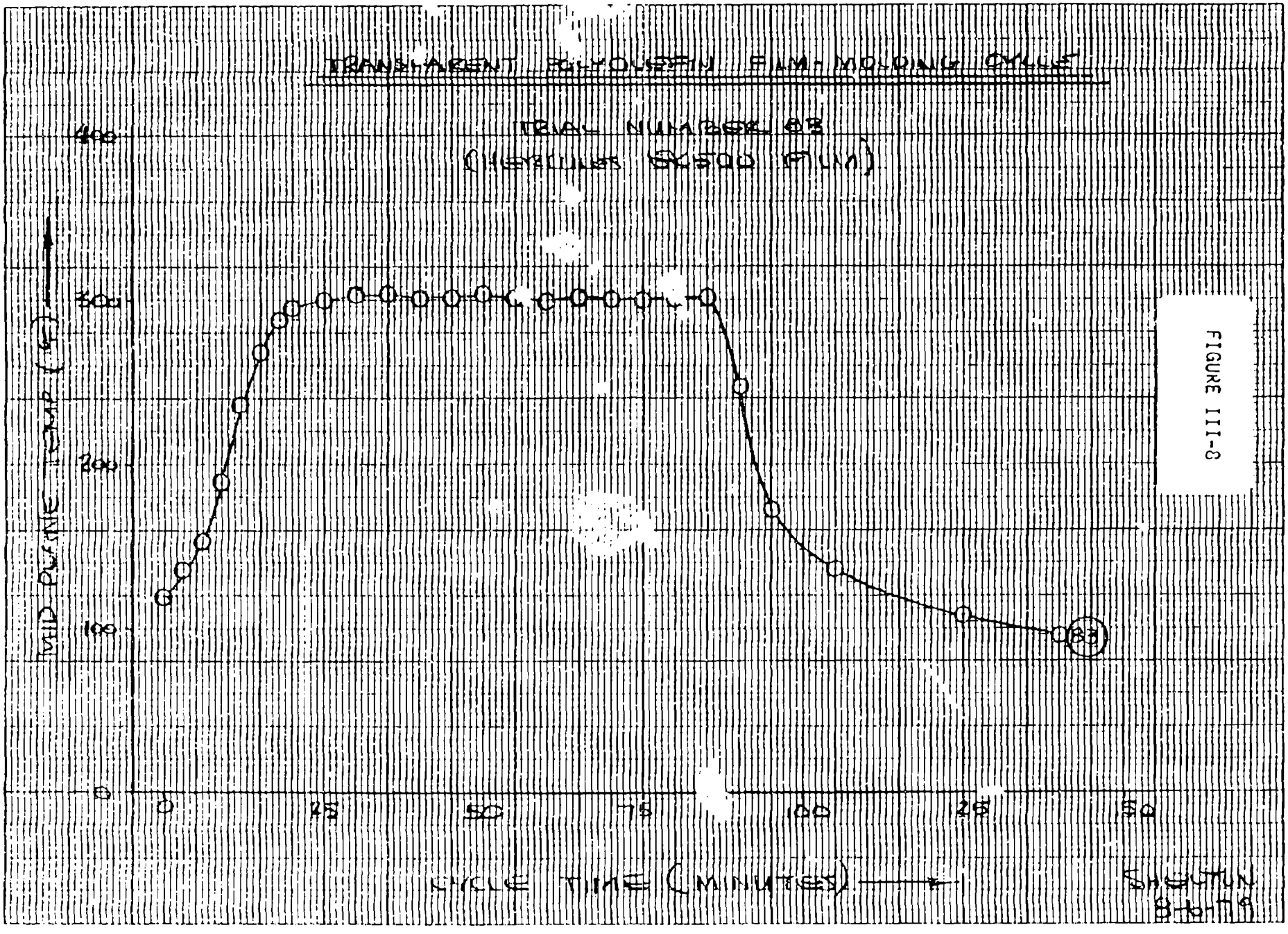


FIGURE III-8

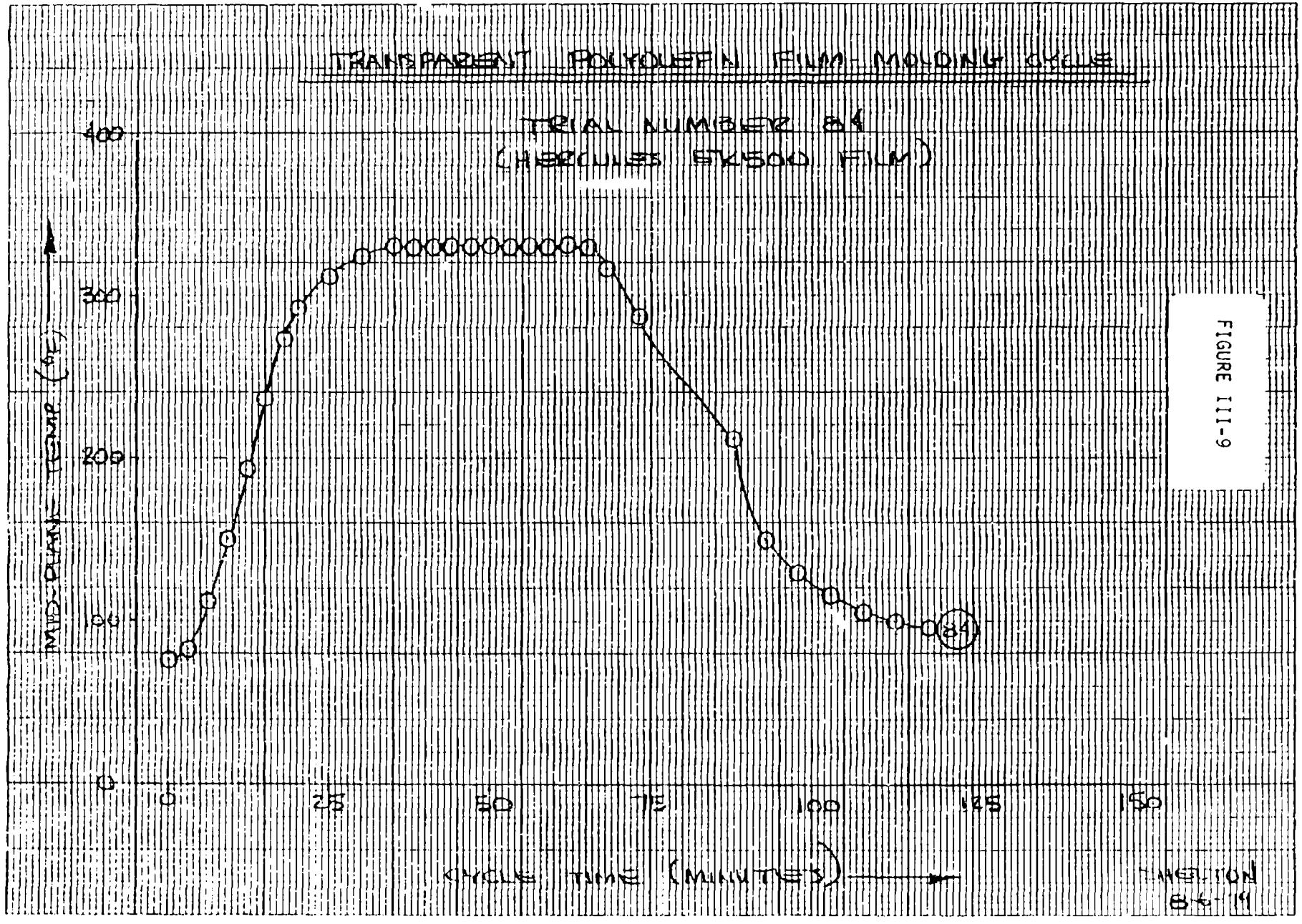


FIGURE III-9

FIGURE III-10

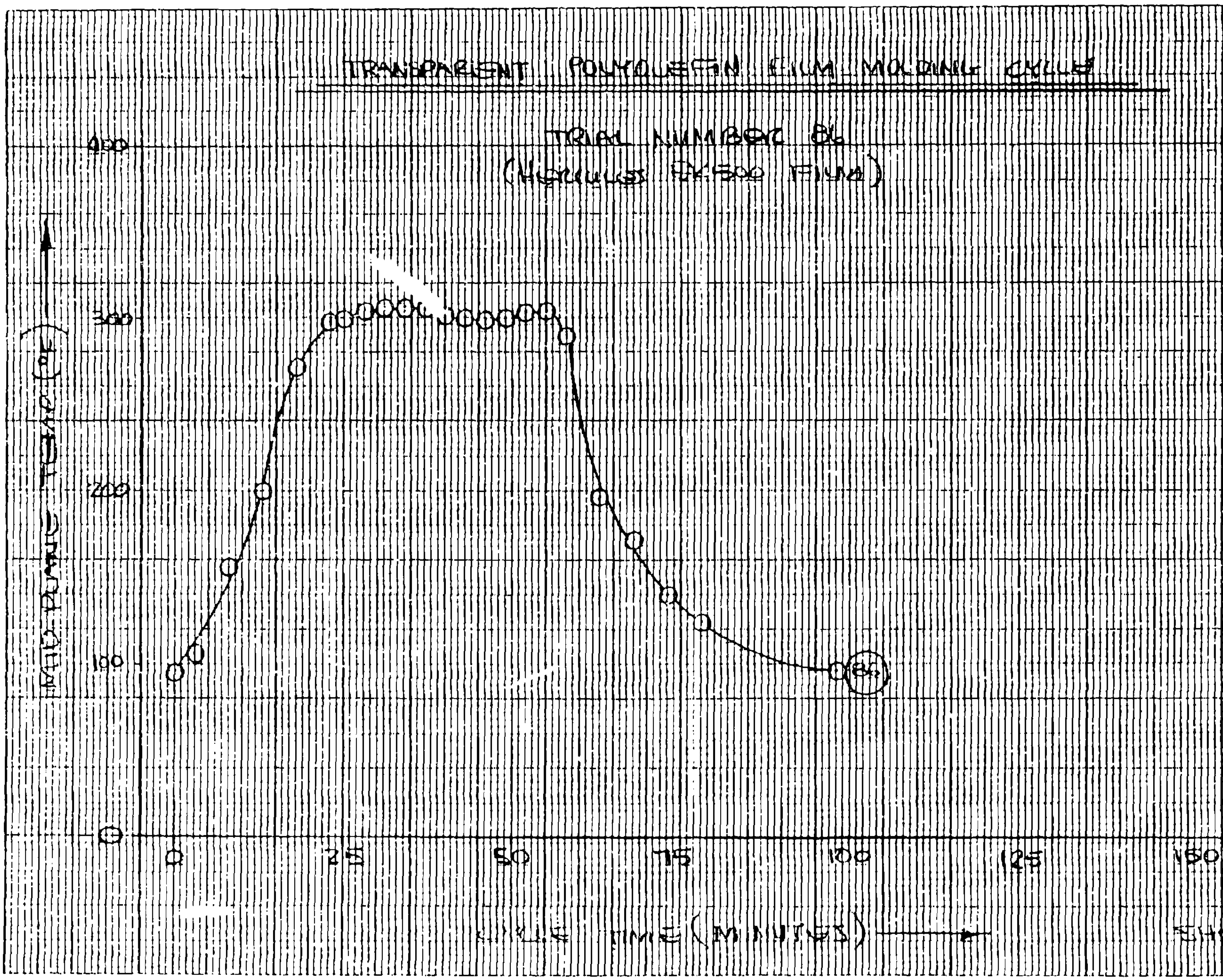


FIGURE III-11

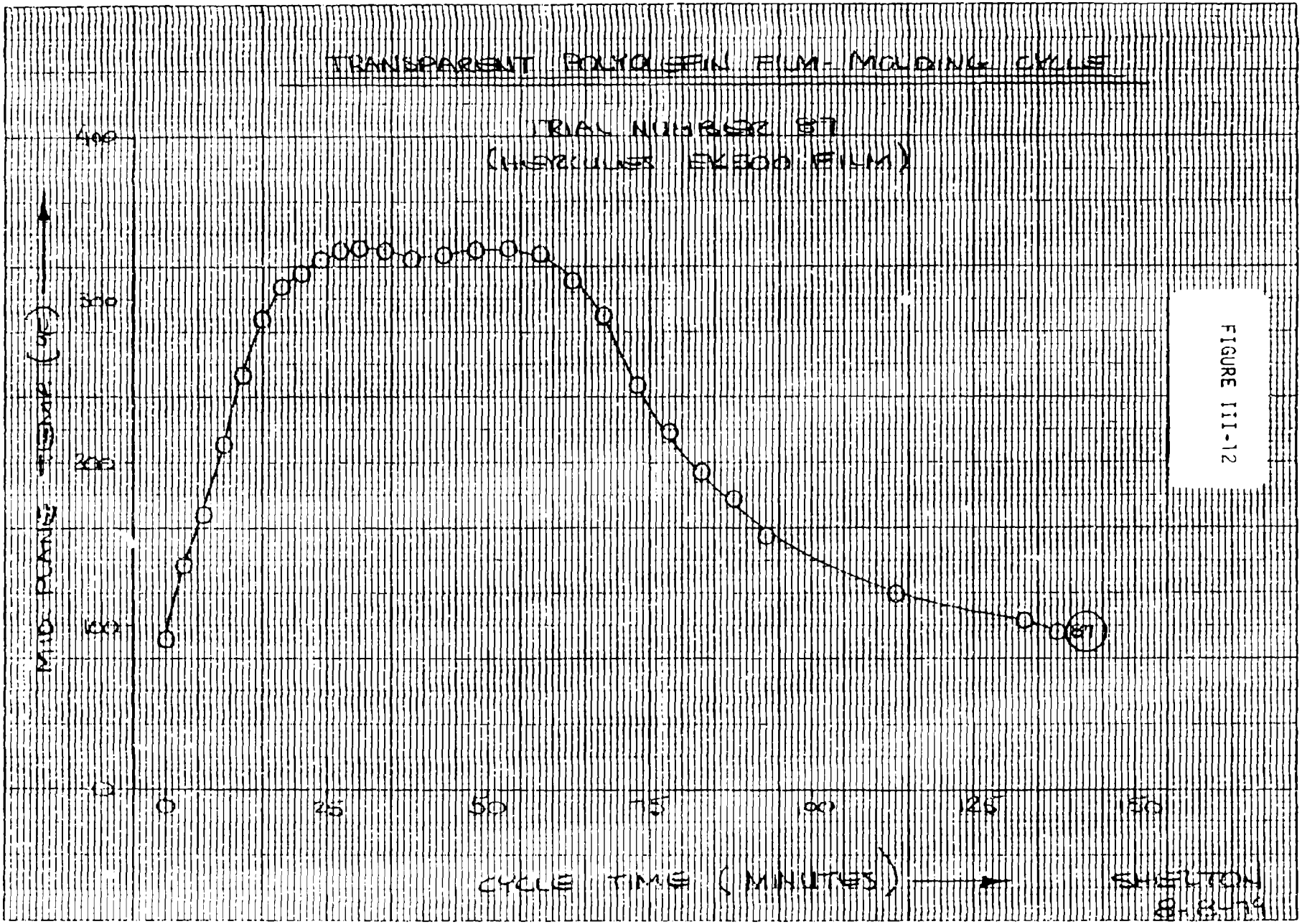


FIGURE III-12

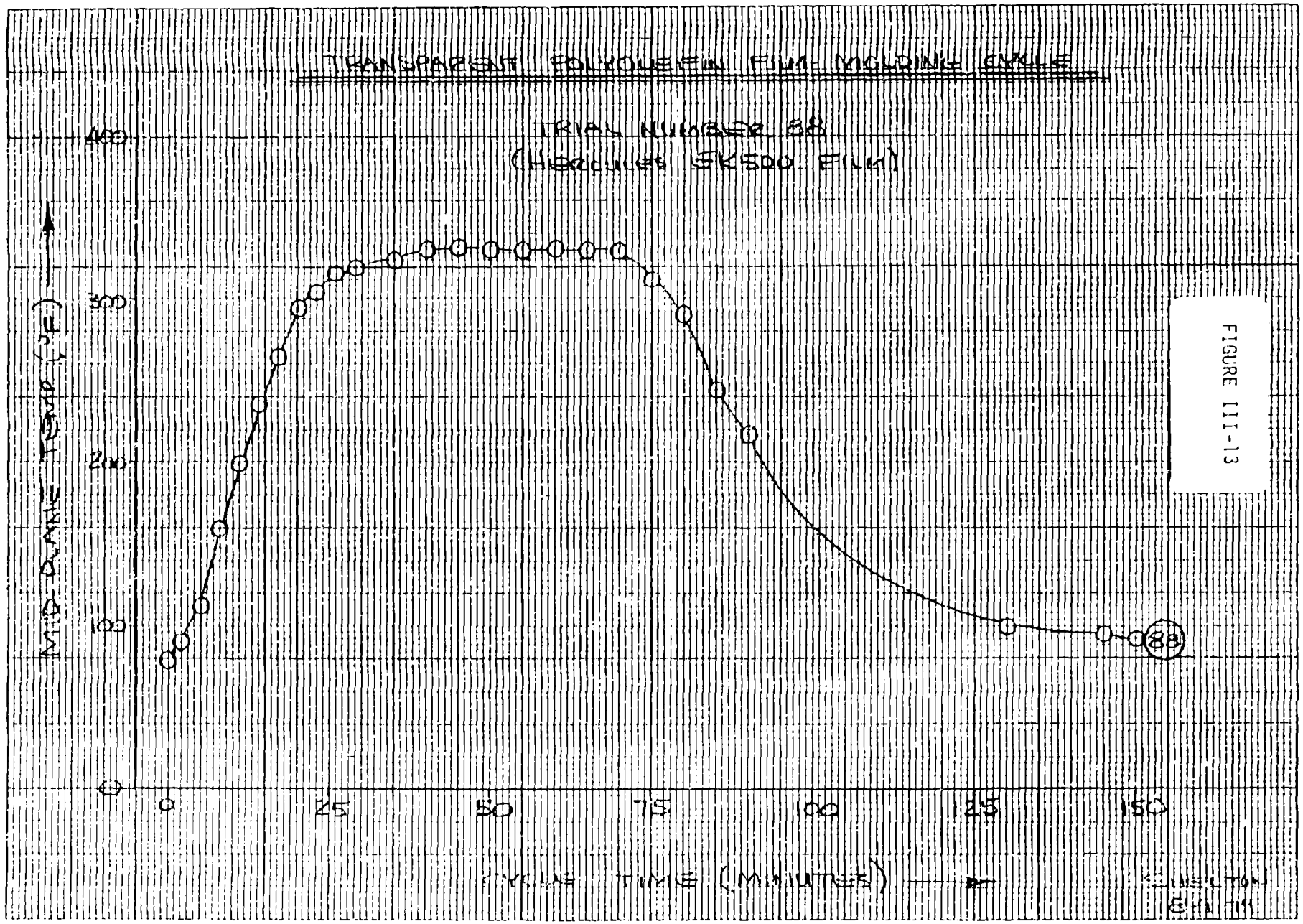


FIGURE III-13

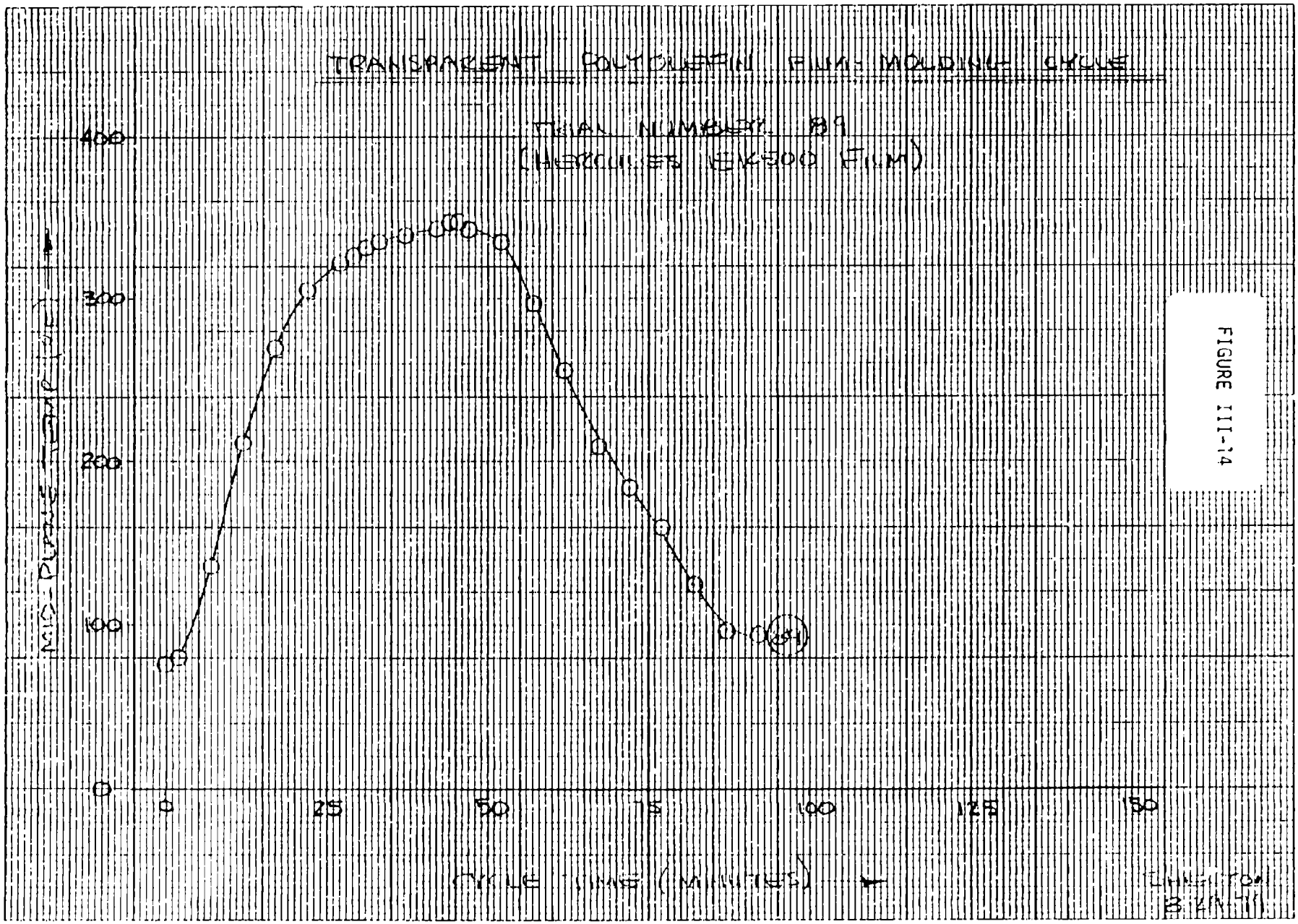


FIGURE III-14

FIGURE III-15

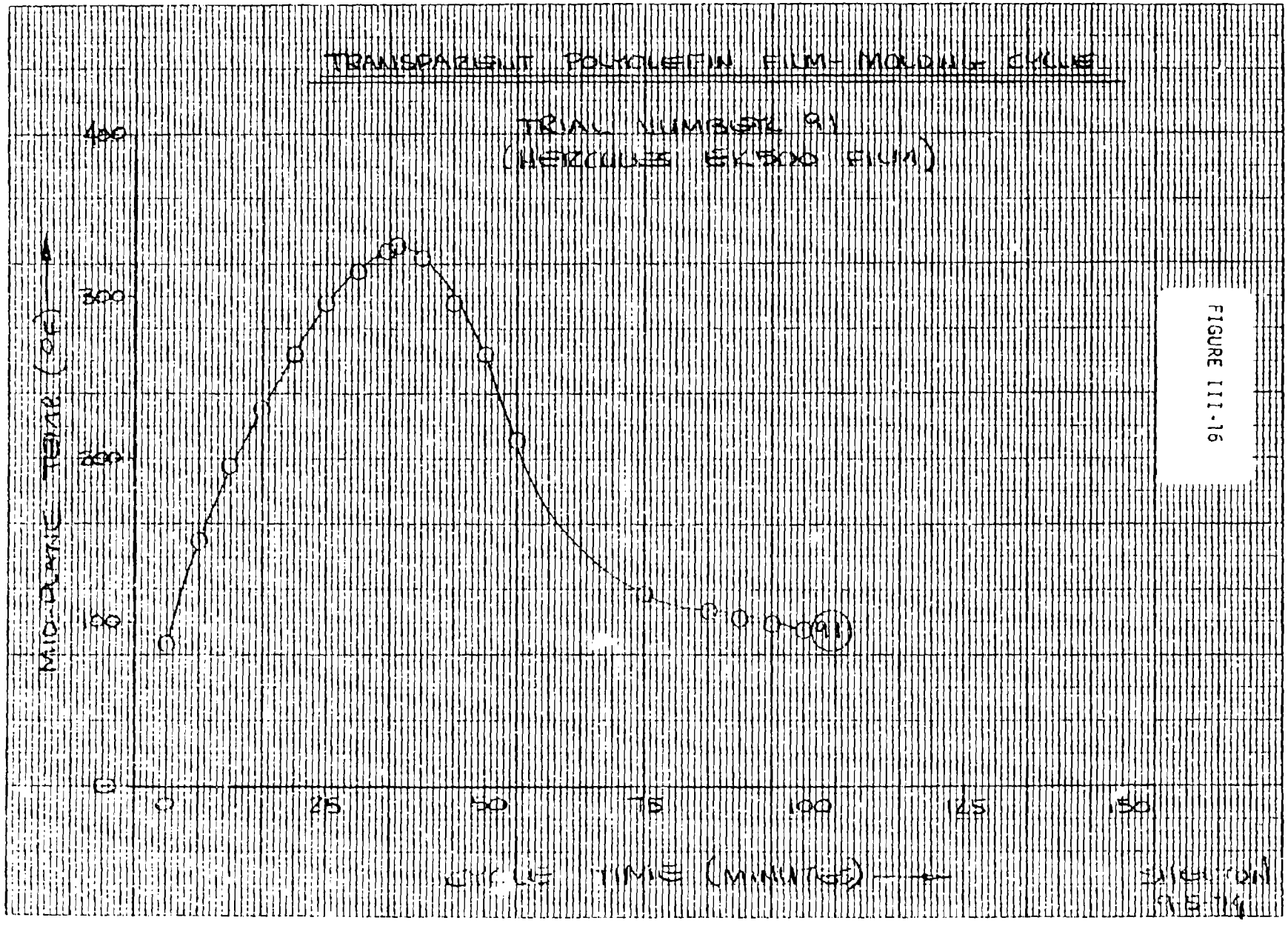


FIGURE III-16

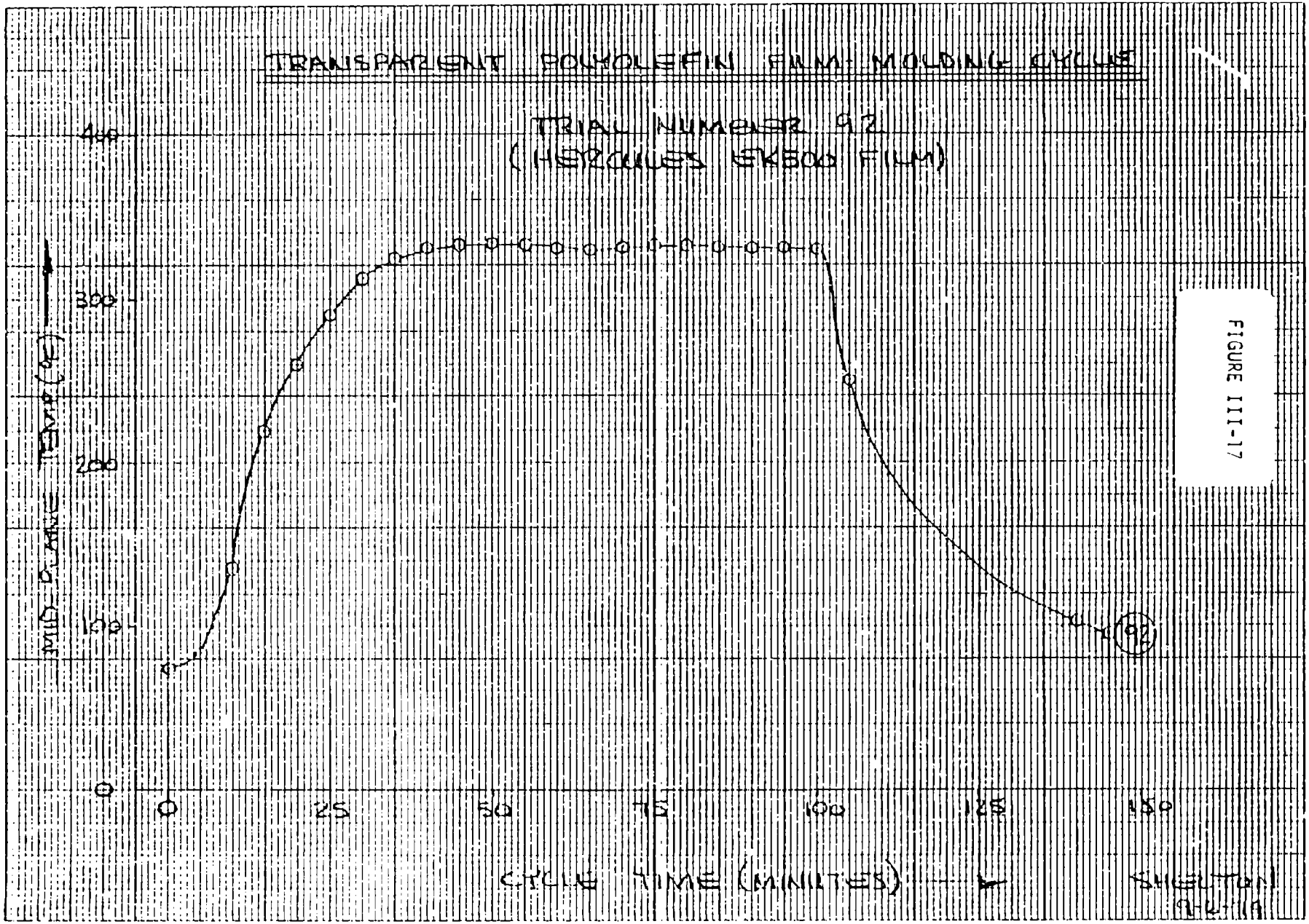


FIGURE III-17

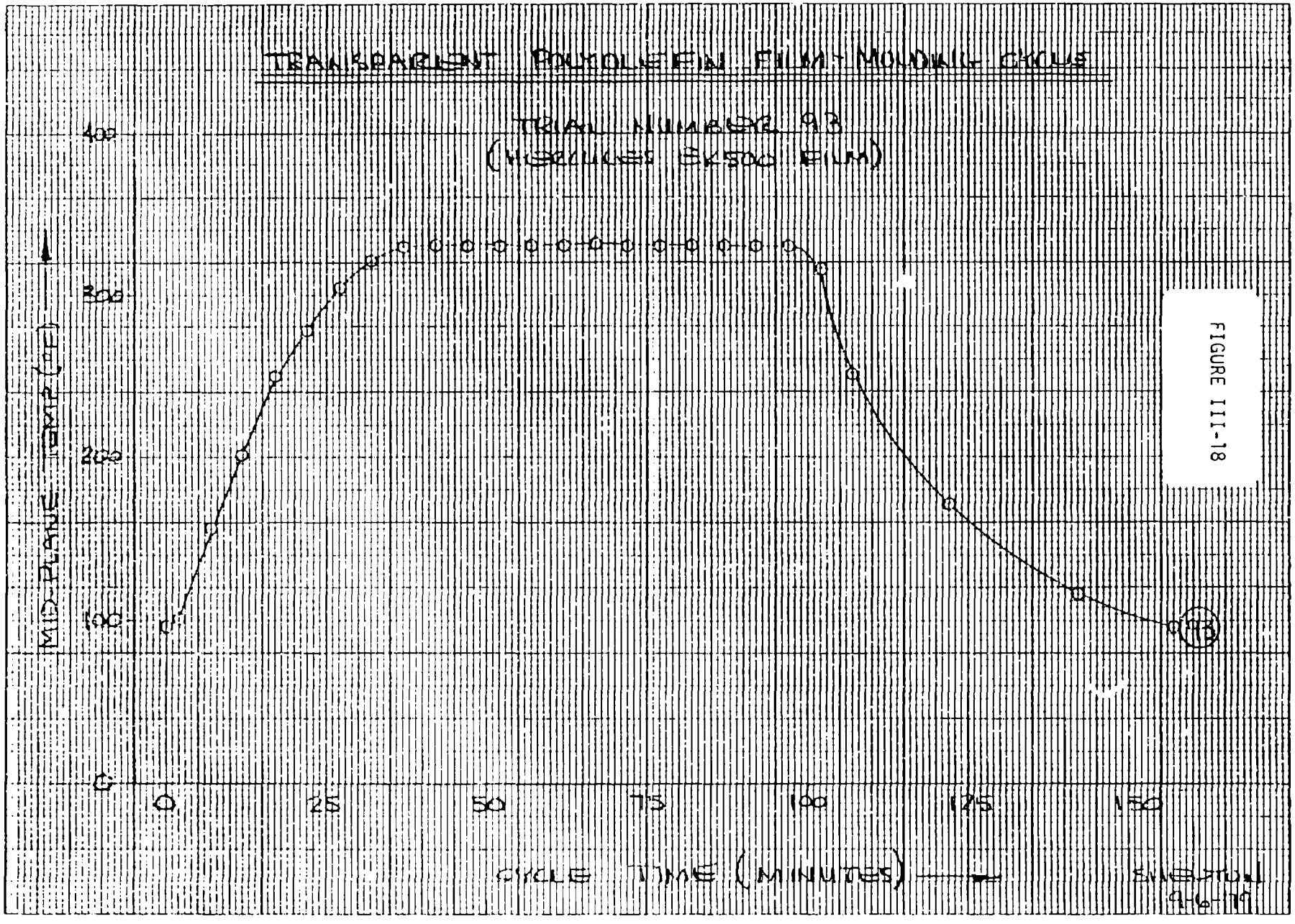


FIGURE III-18

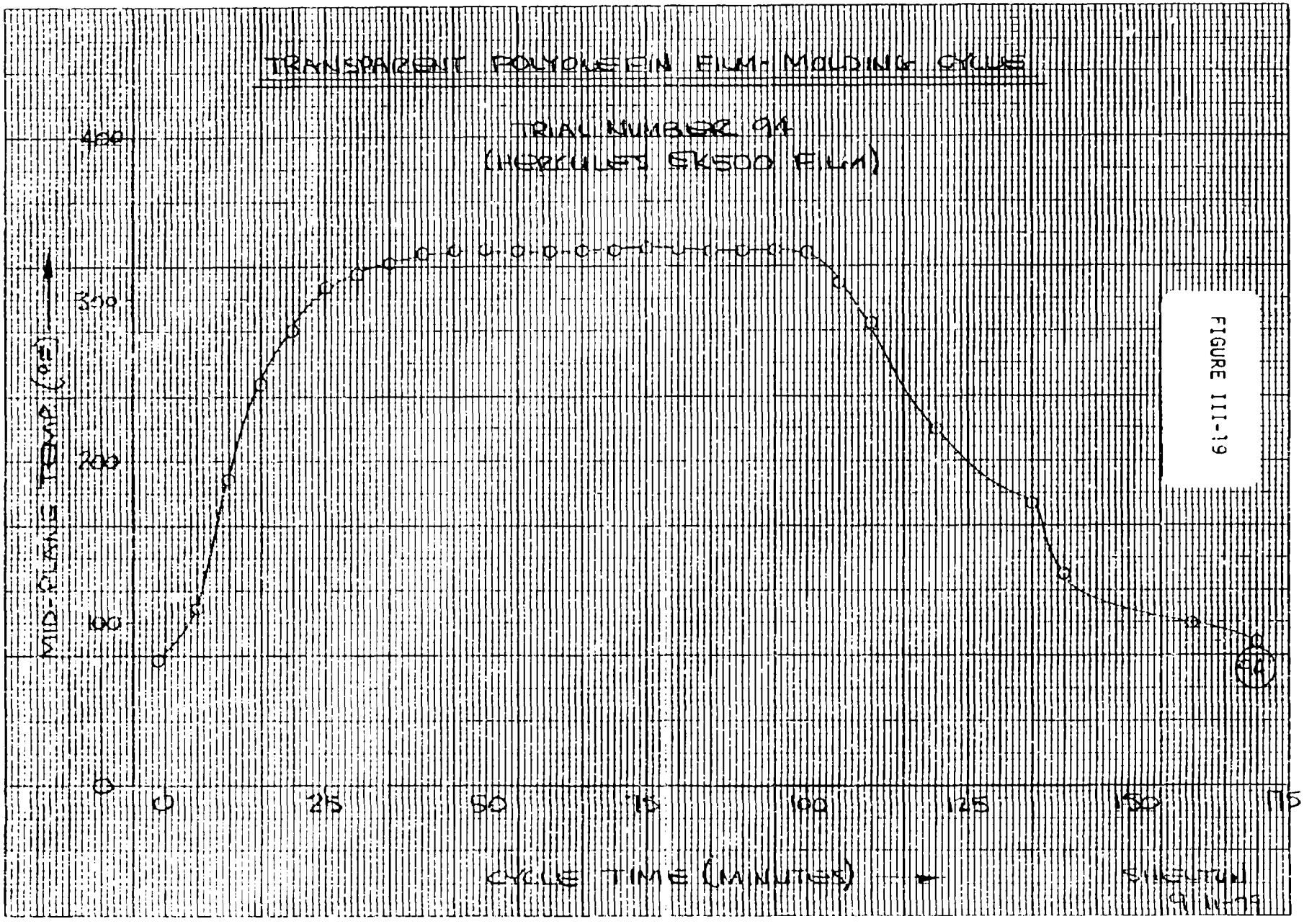


FIGURE III-19

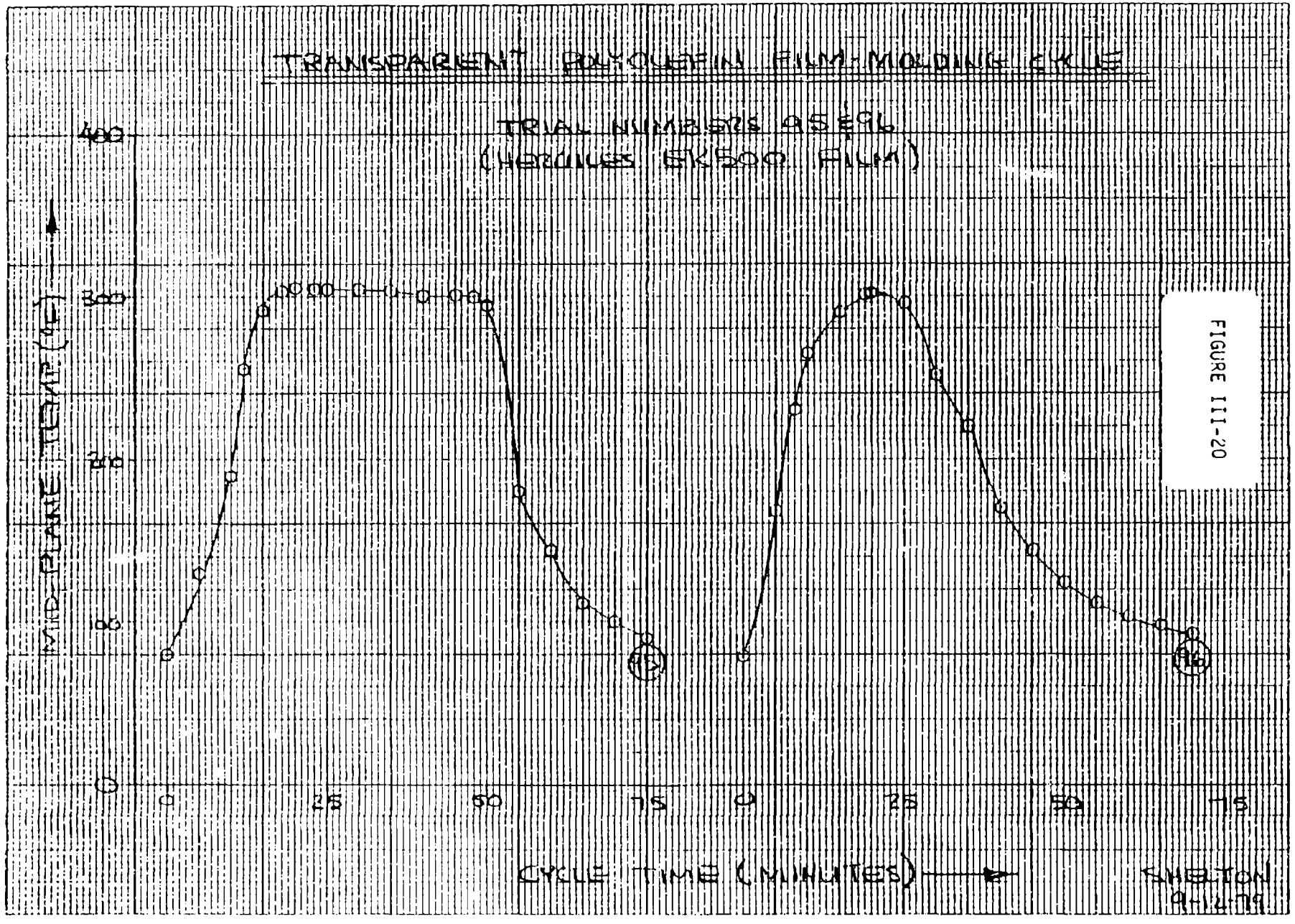


FIGURE III-20

FIGURE III-21

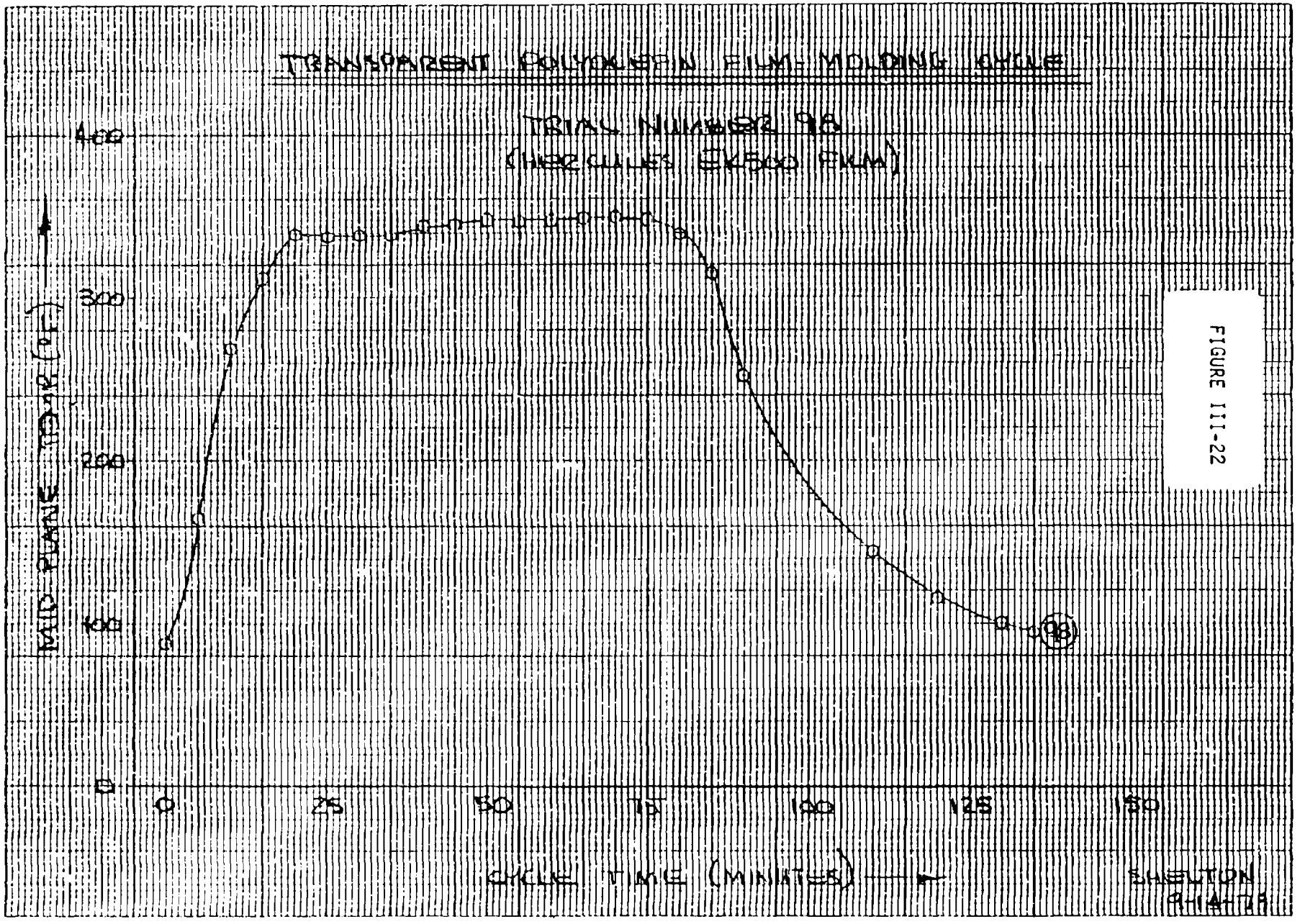


FIGURE III-22

FIGURE III-23

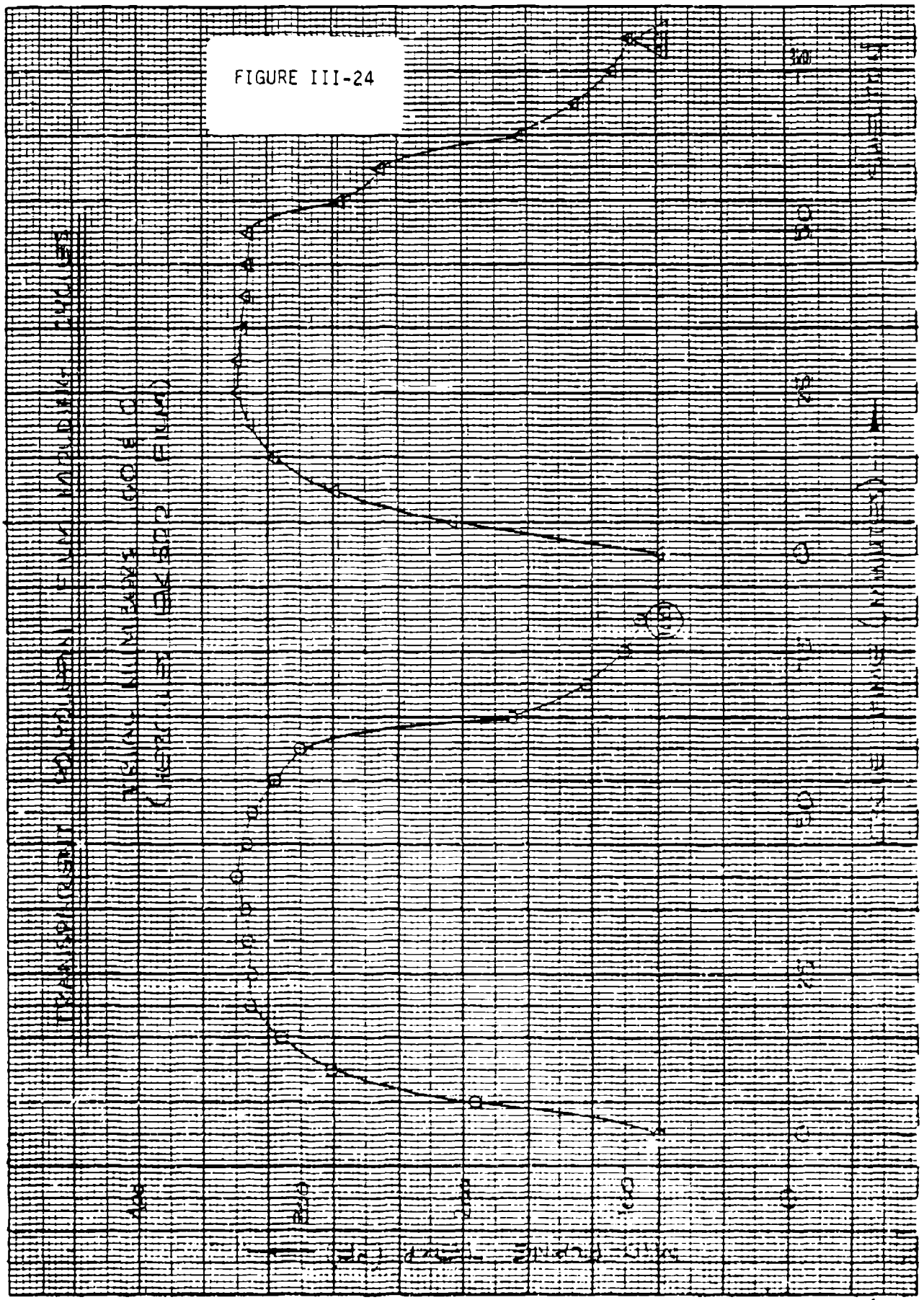
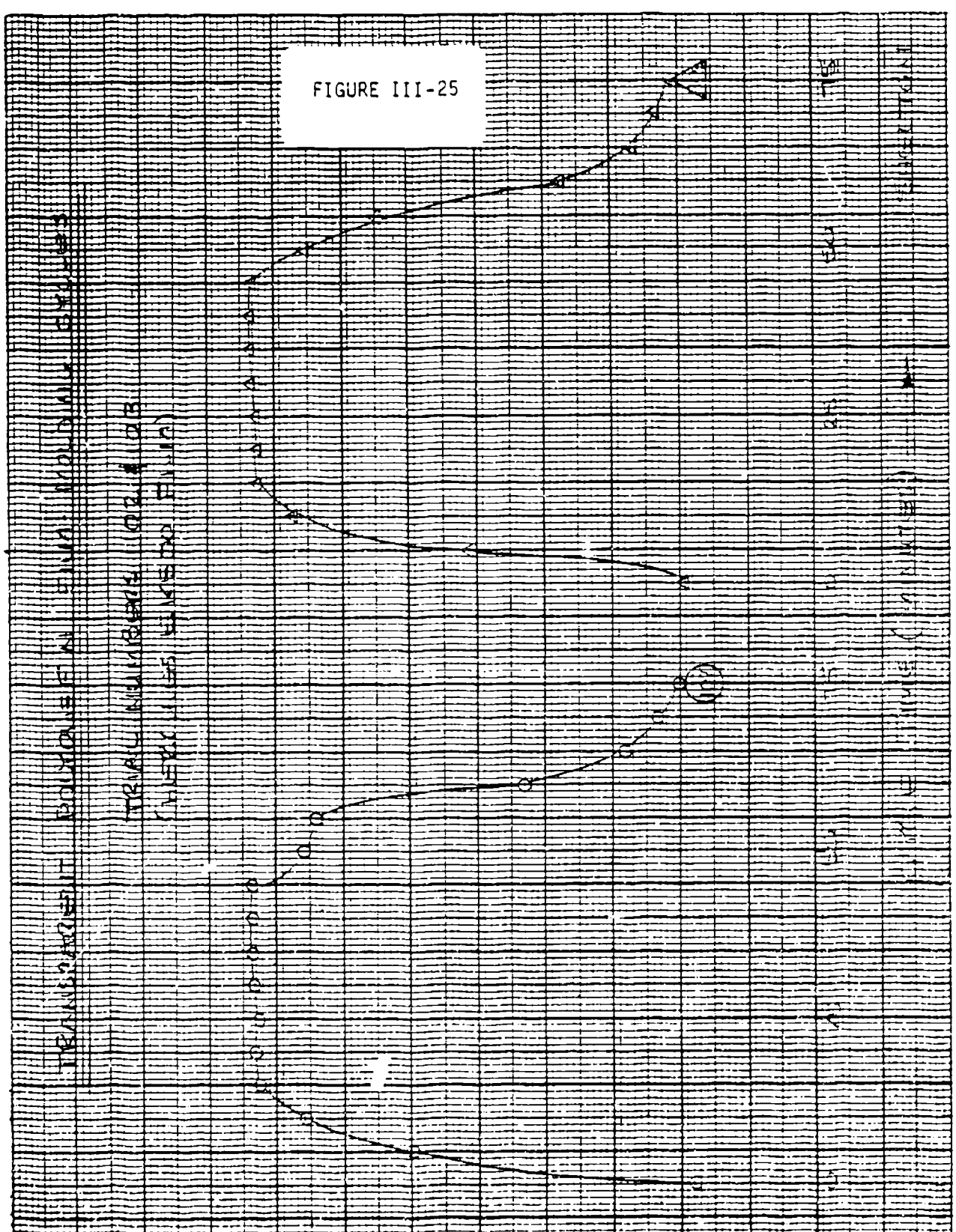


FIGURE III-25



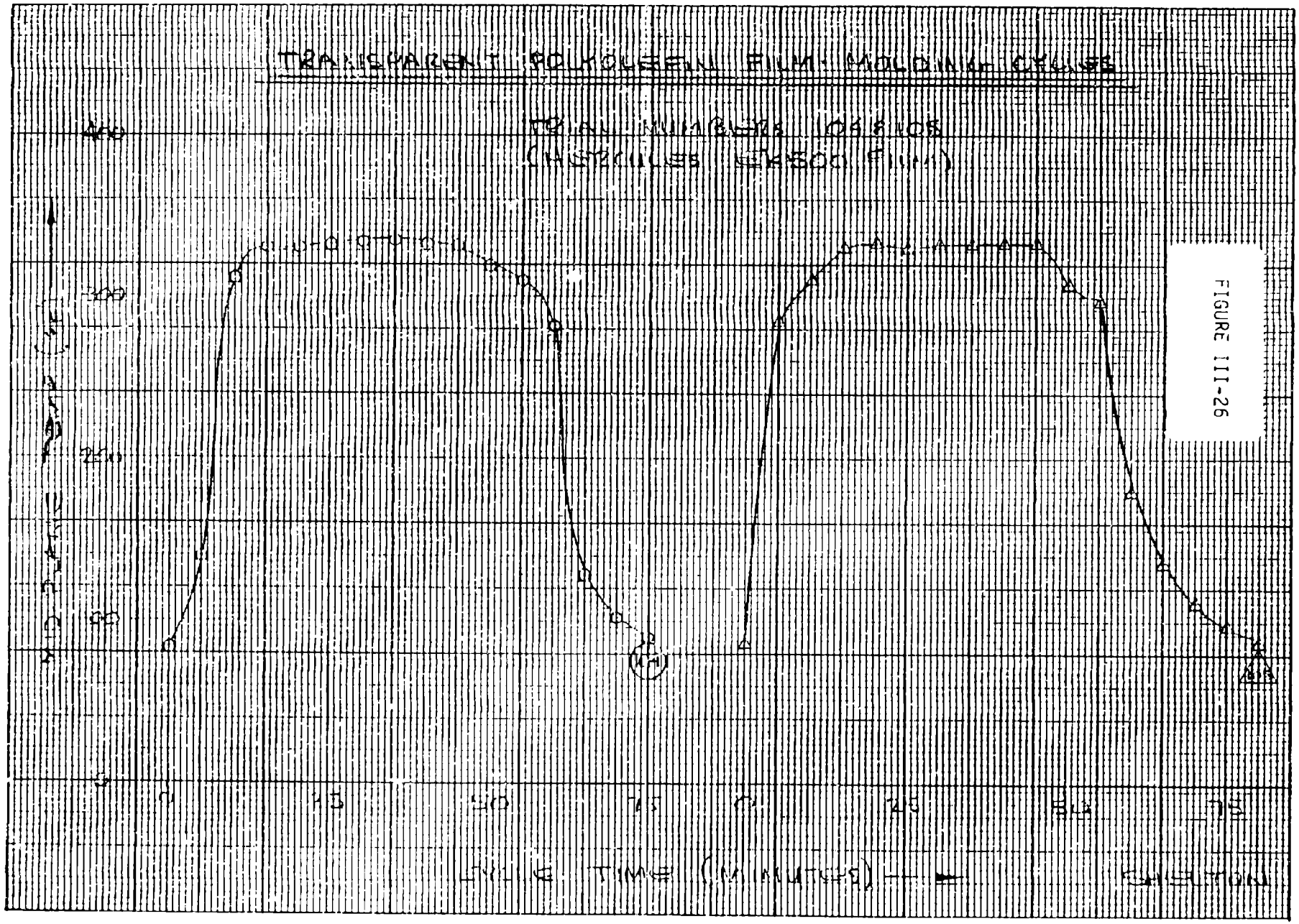


FIGURE III-26

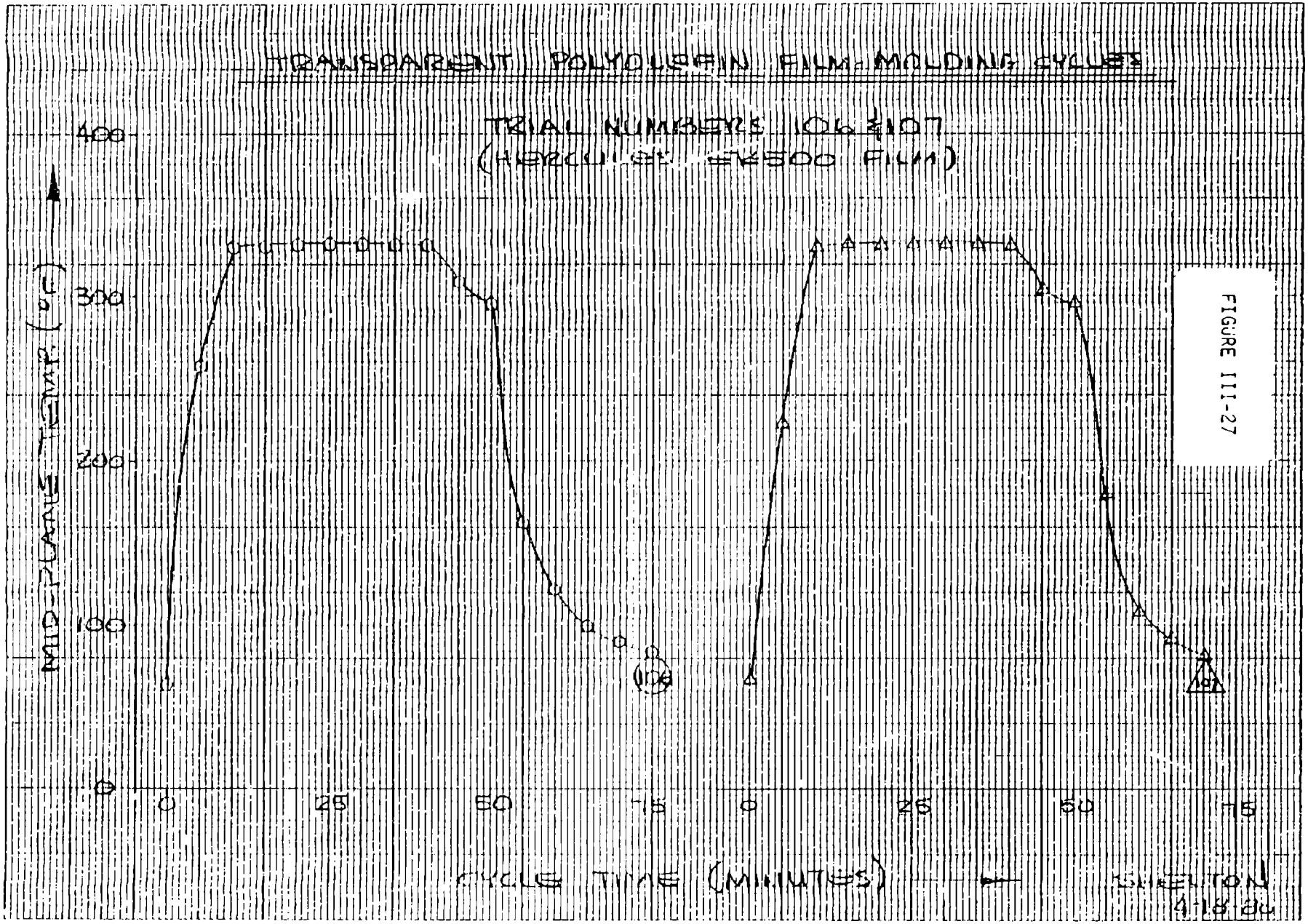


FIGURE III-27

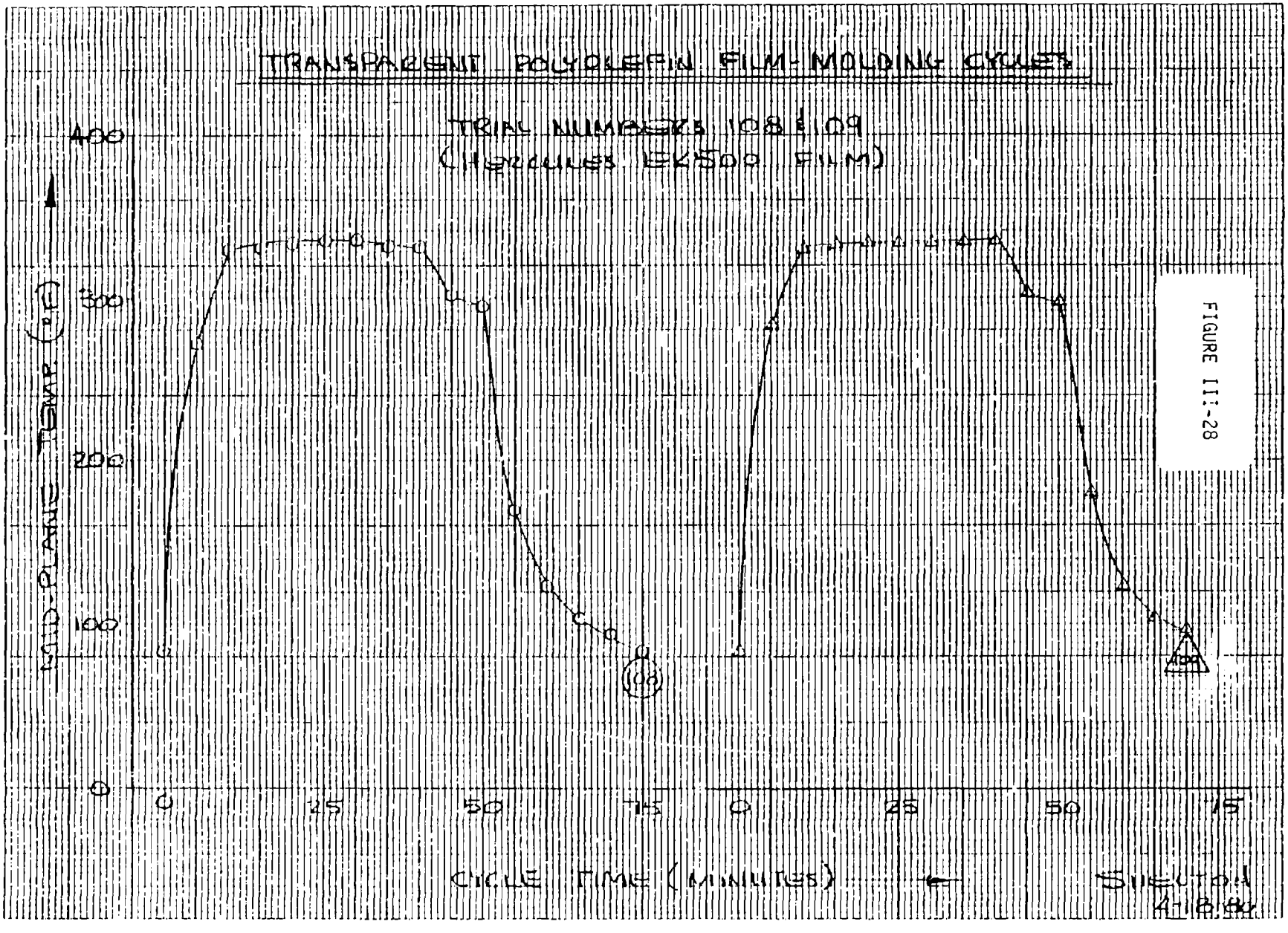


FIGURE II-28

FIGURE III-29

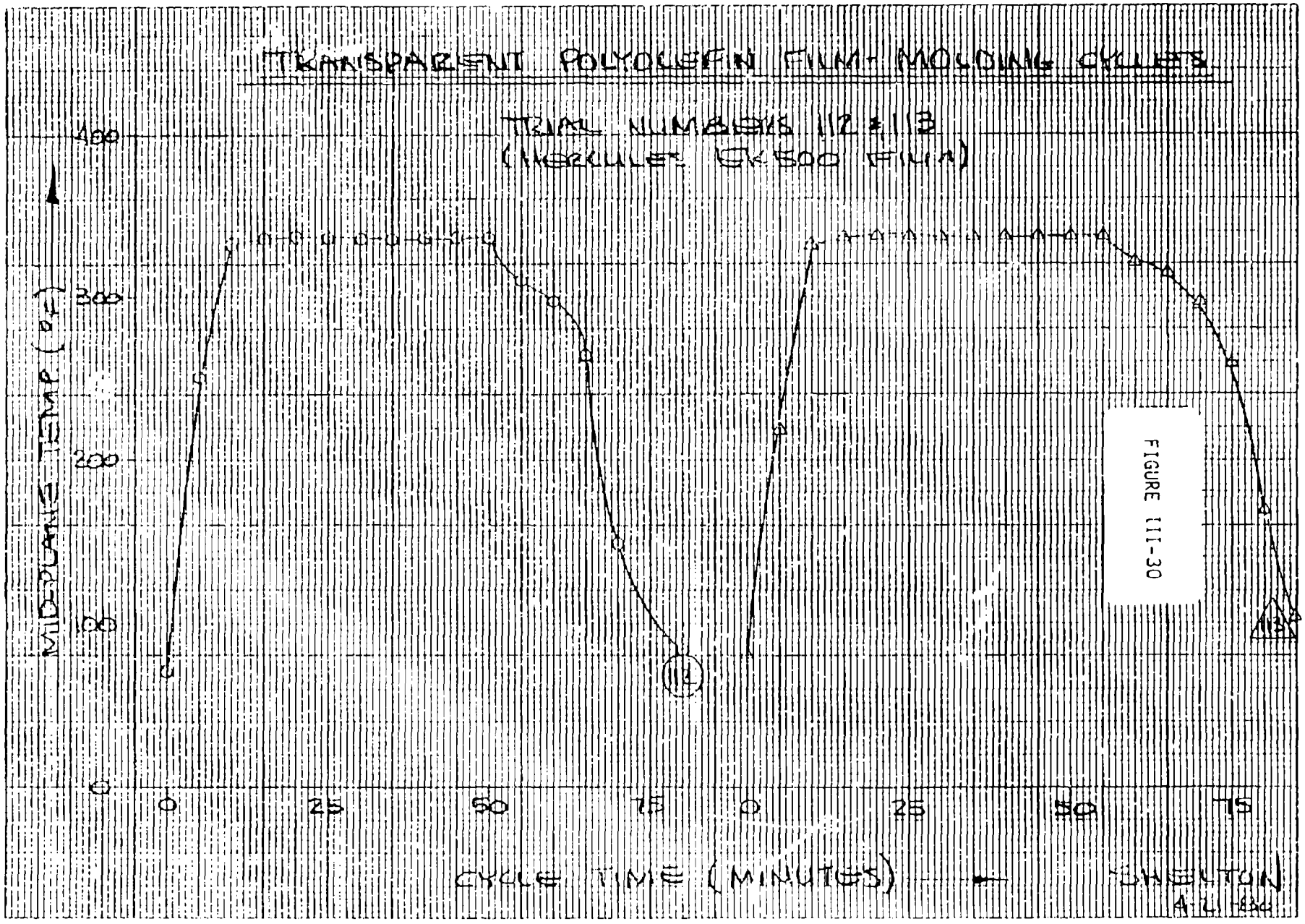


FIGURE III-30

FIGURE III-31

FIGURE III-32

FIGURE III-33

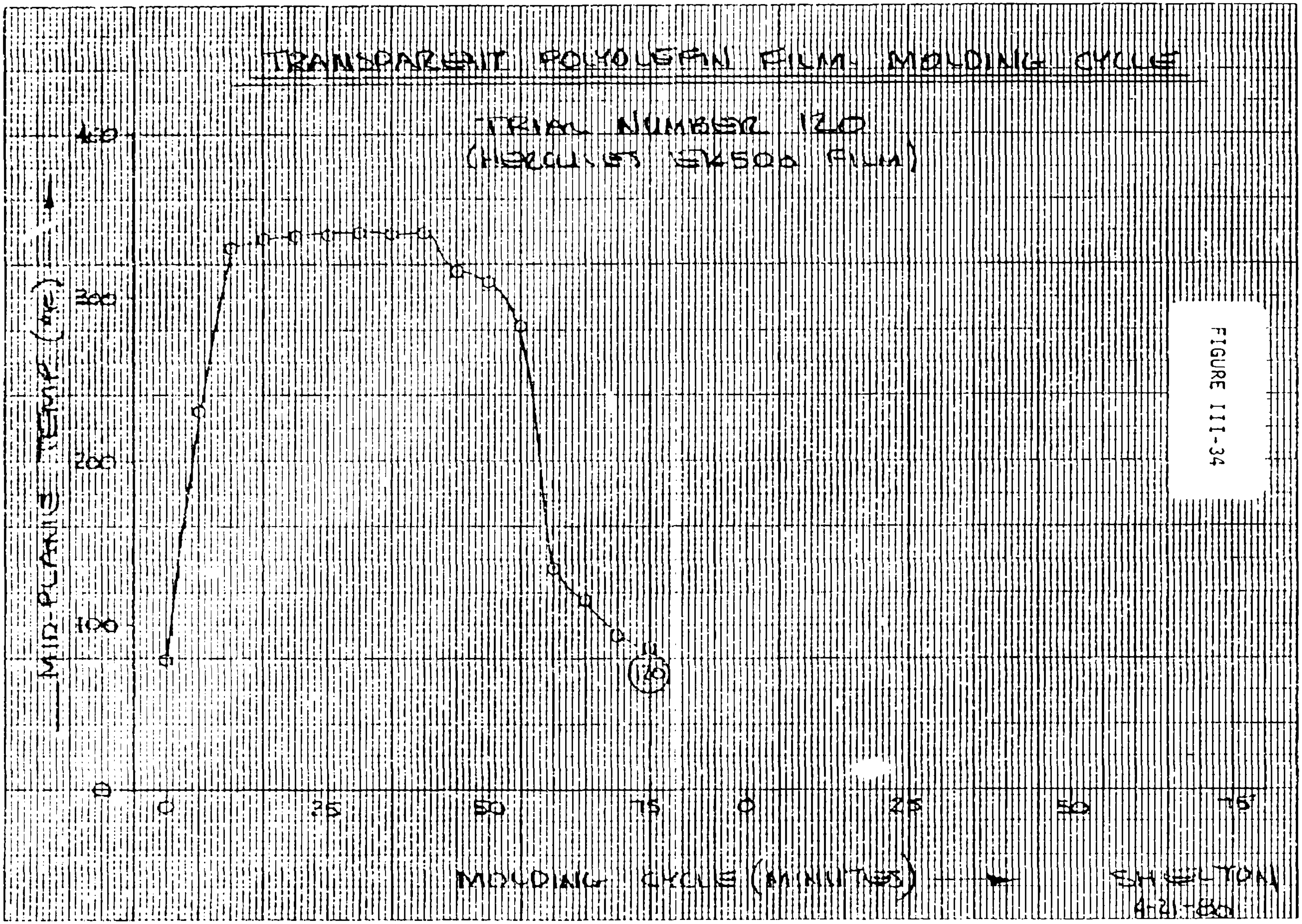


FIGURE III-34

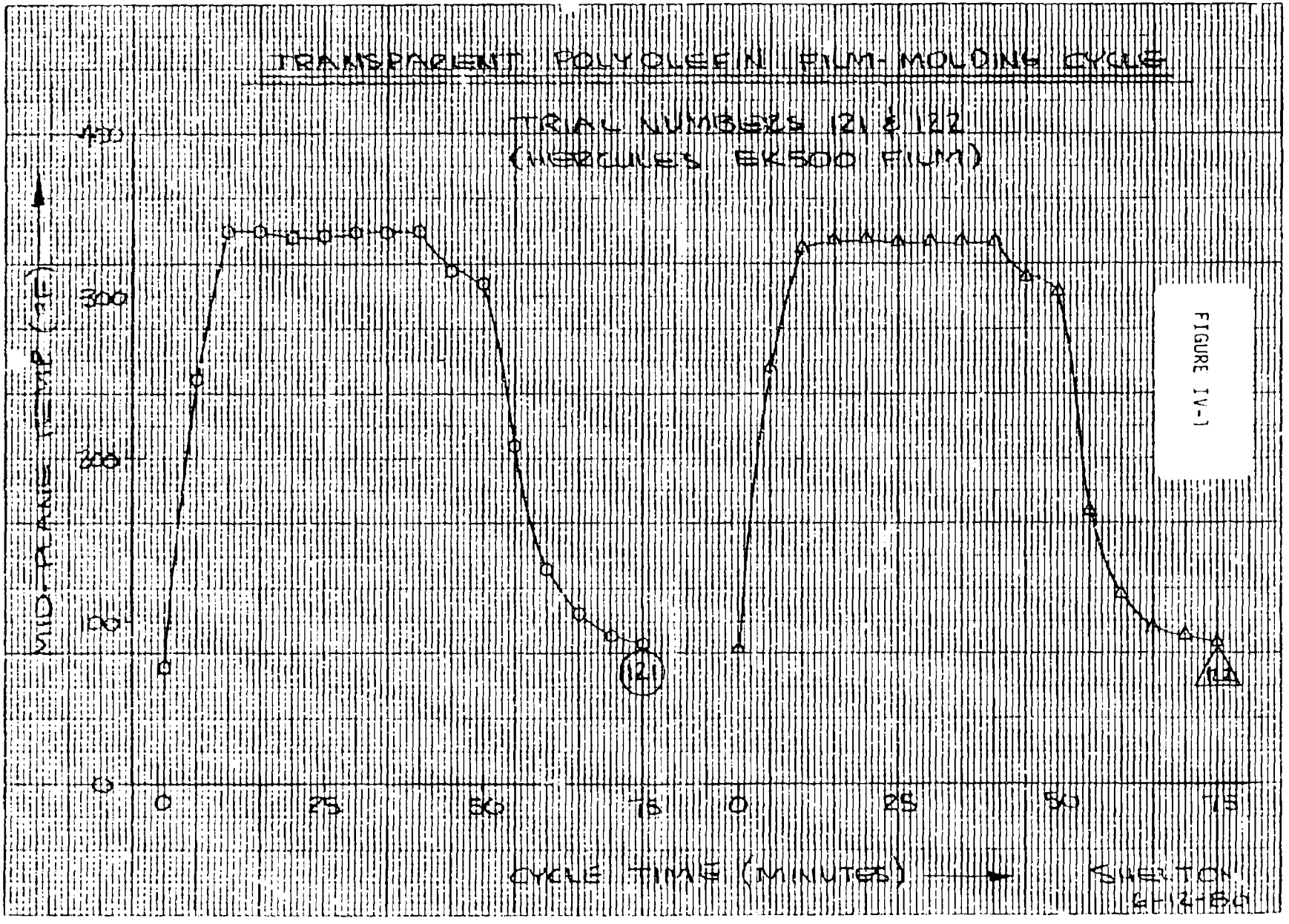


FIGURE IV-1

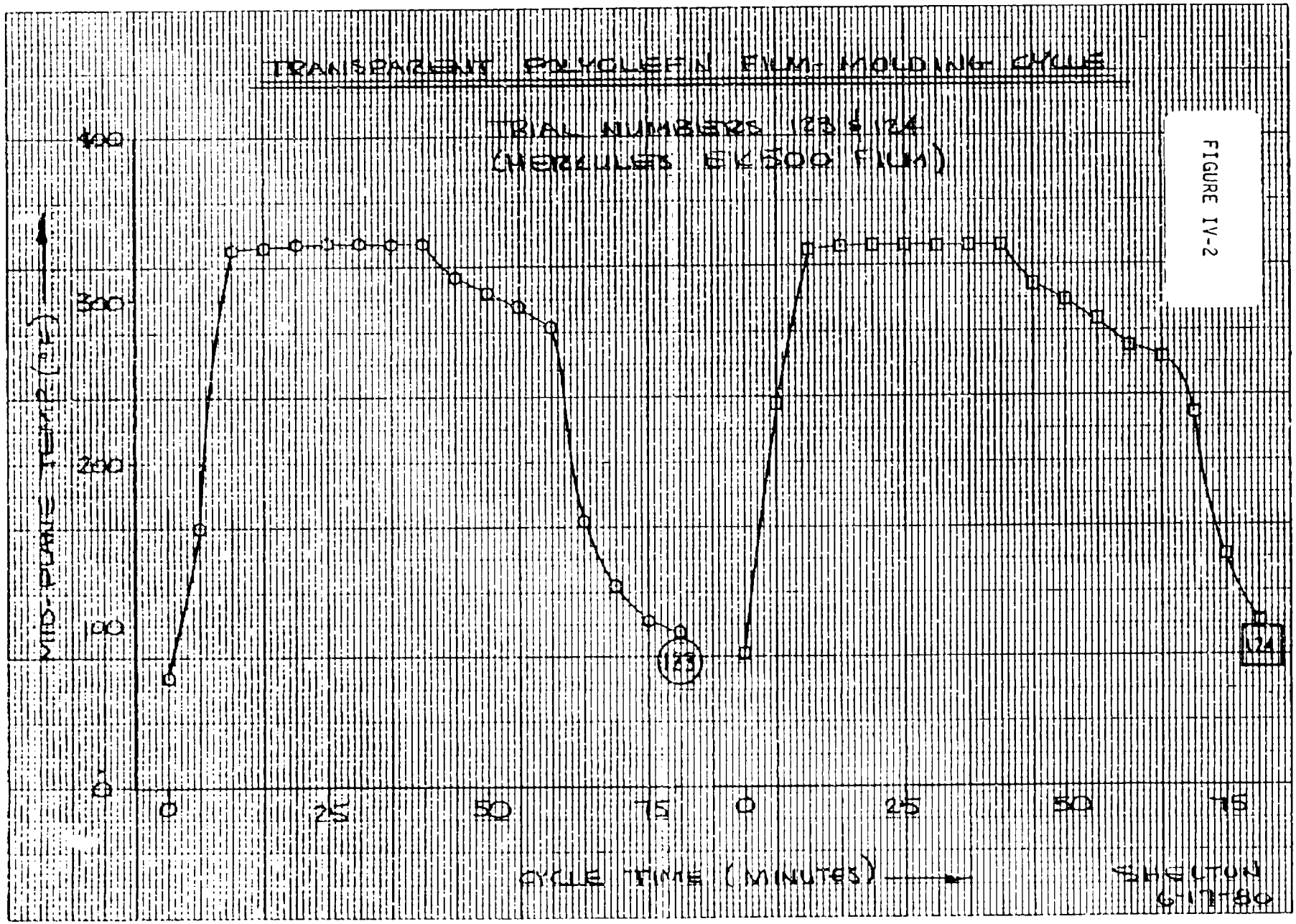


FIGURE IV-2

FIGURE IV-3

FIGURE IV-4

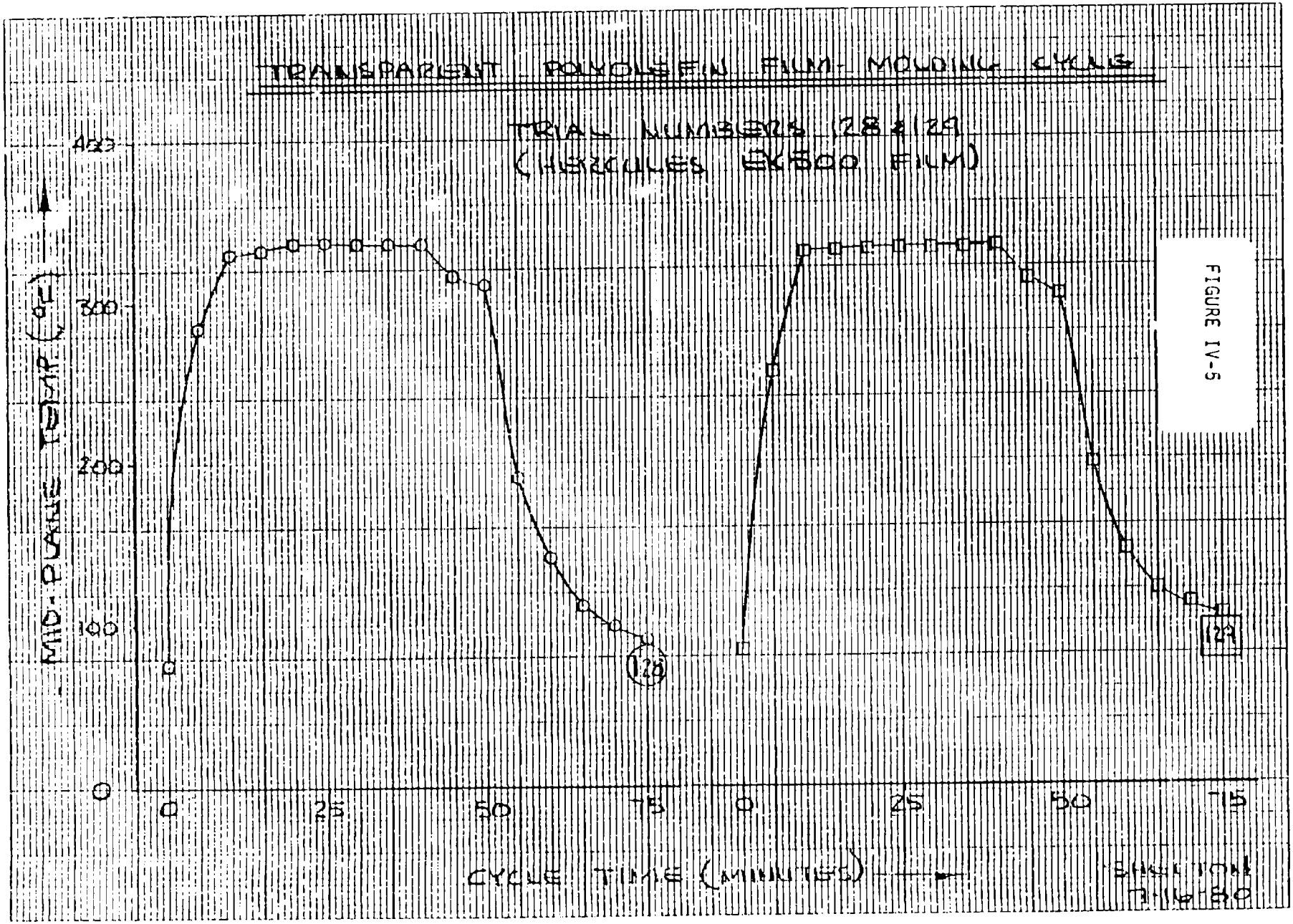

TRANSPARENT POLYOLEFIN FILM MOLDING CYCLE
TRIAL NUMBERS 28 & 29
(HERCULES EXACT FILM)
MID-PLANE TEMP (°F)
400
300
200
100
0
0
25
50
75
0
25
50
CYCLE TIME (MINUTES)
28
29

FIGURE IV-5

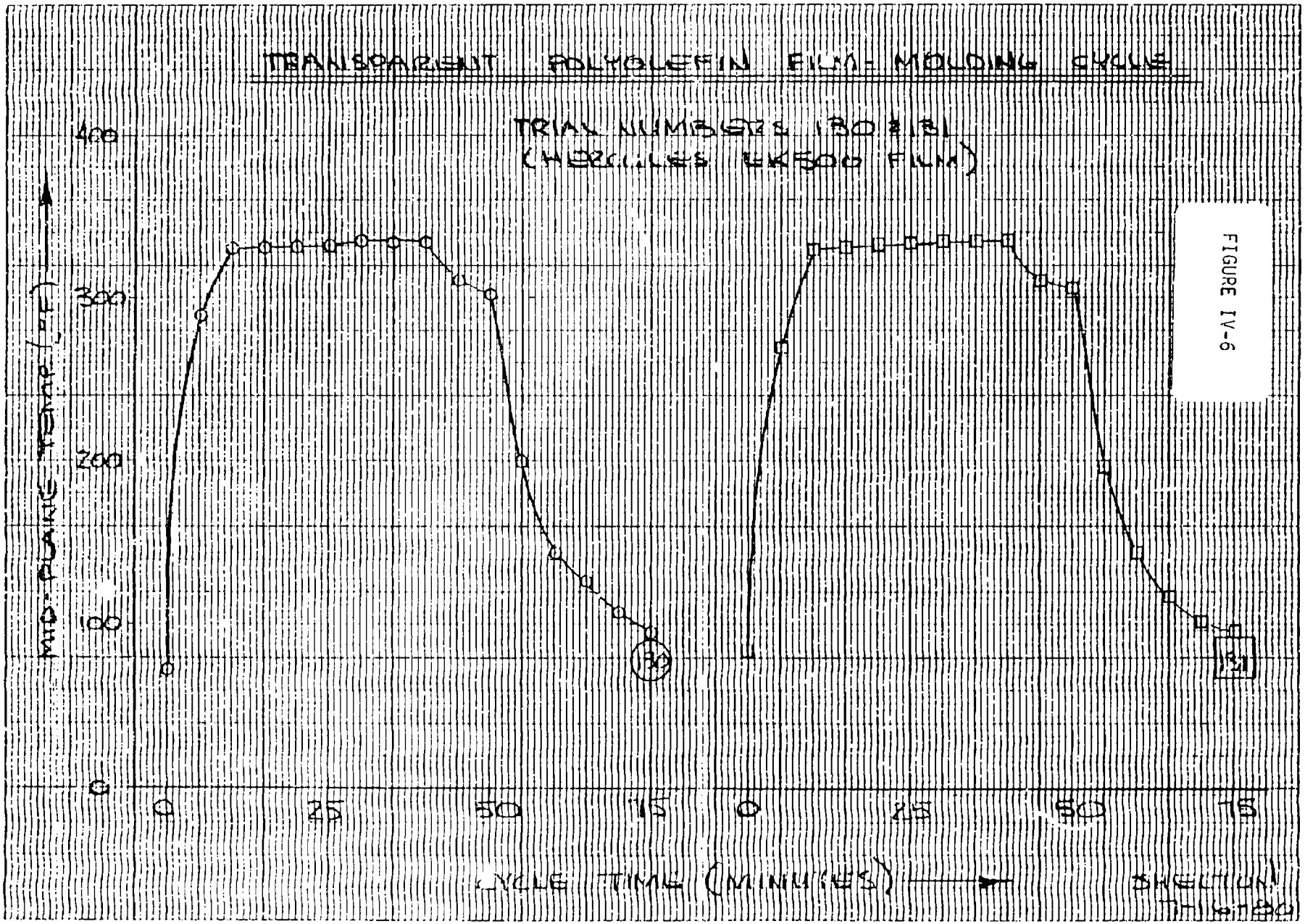


FIGURE IV-6

FIGURE IV-7

TRANSPARENT POLYOLEFIN FILM: MODULUS CYCLE
TRIAL NUMBER 182
(HEREAFTER 1BZ)
CROSSLINKED FILM
CYCLES TO FAILURE
CRAZING (%)
50
25
0
10
50
25
0
300
200
100
RATIO PLASTIC STRAIN (%)

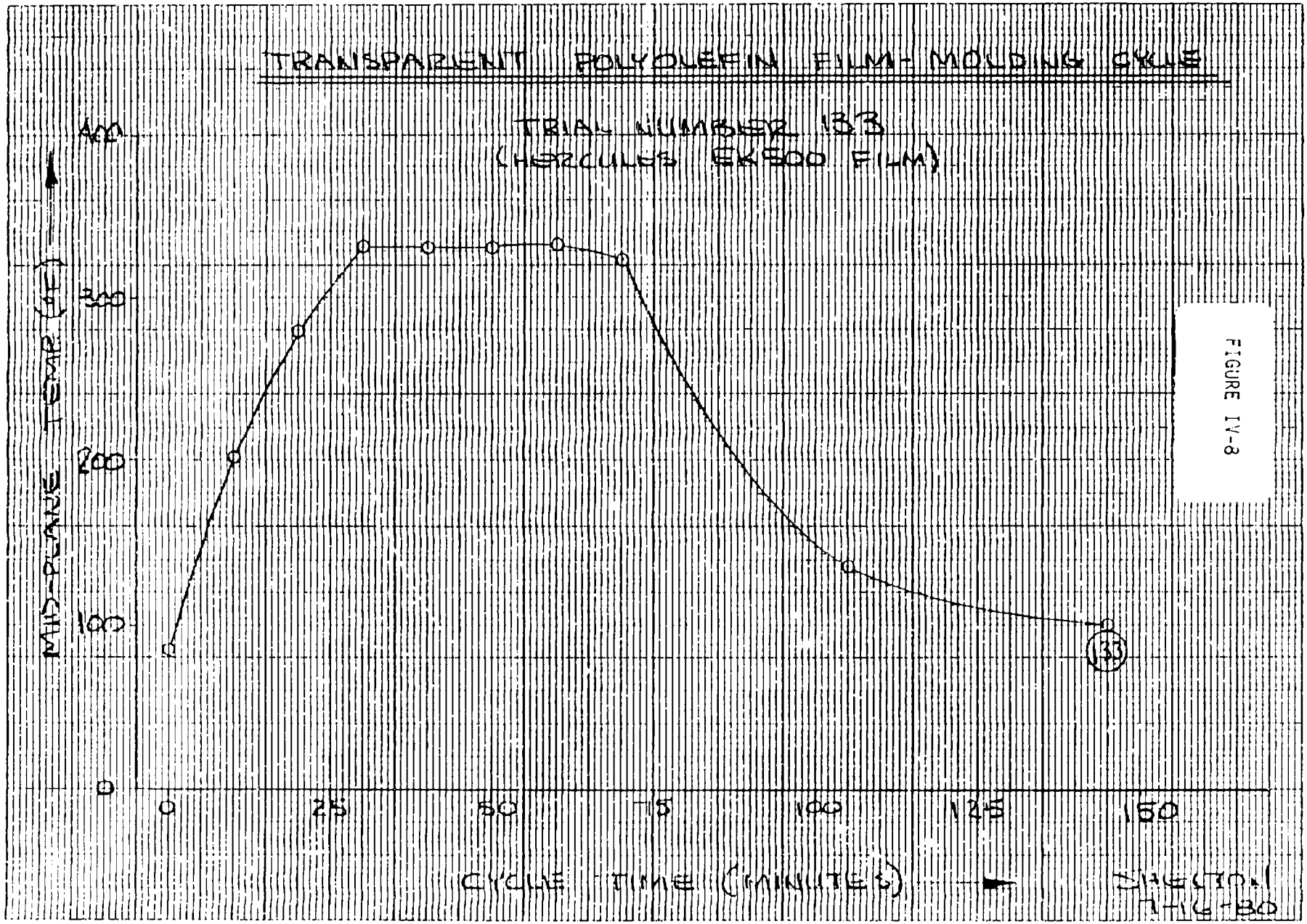


FIGURE IV-8

FIGURE IV-9

TRANSPARENT POLYOLEFIN FILM MOLDING CYCLE
TRANSMISSION (24 HOUR) 1.0 MIL FILM
MID-PLANE TEMP (°F)
TIME (SECONDS)

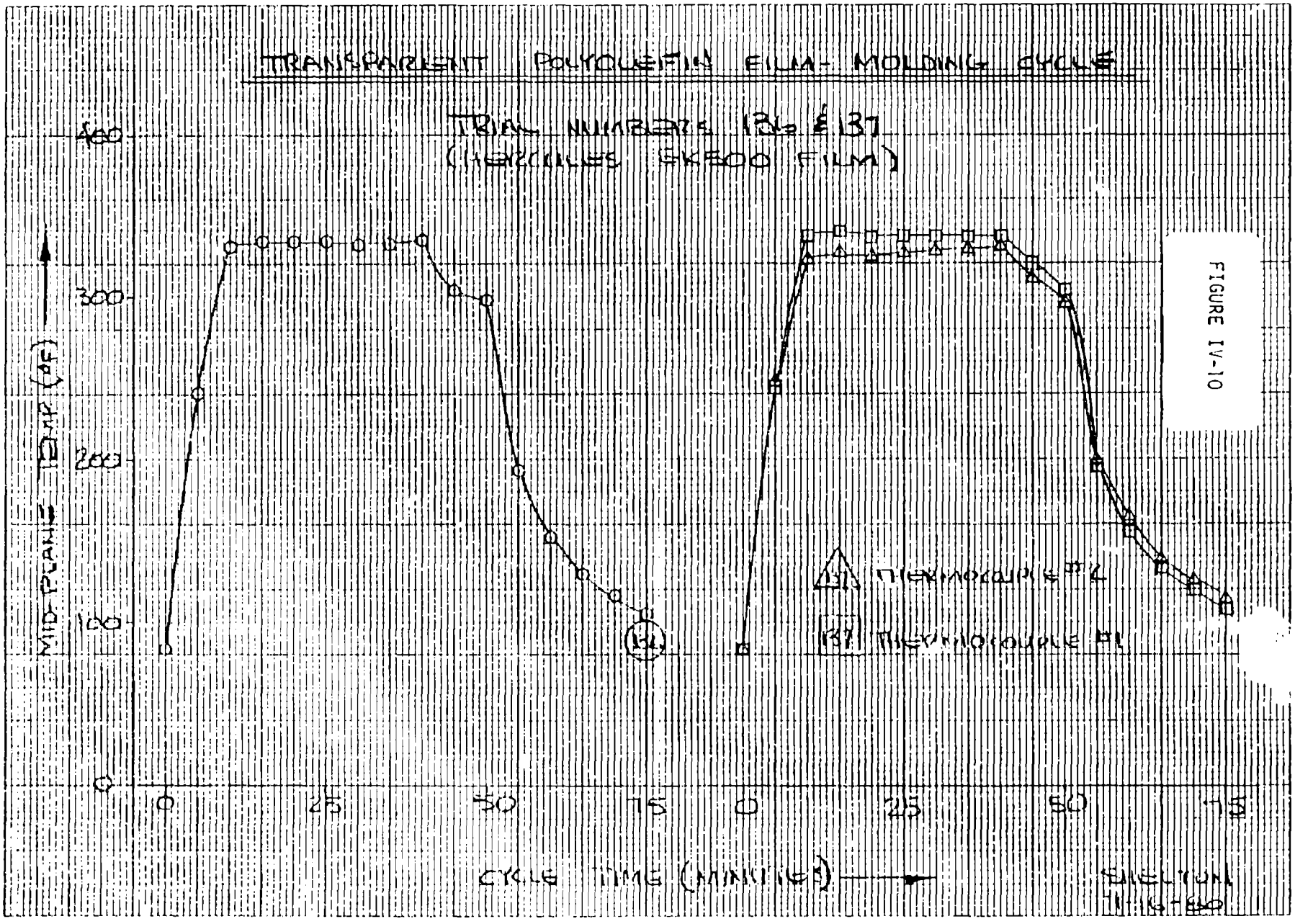


FIGURE IV-10

FIGURE VI-1

TRANSPARENT FILM MOLDING CYCLE
INITIAL NUMBER OF 3 MIL FILMS
(UNSTRETCHED)
MELT TEMP (°F)
MOLD TEMP (°F)
TIME (SEC)
0
60
120
180
240
300
360
400
440
480

FIGURE VI-2

FIGURE VI-3

TRANSPARENCY WITH MOLDING CYCLE
POLYCARBONATE FILM
TRANSMITTANCE (%)
(THICKNESS 0.254 mm)
400
300
200
100
0
0
50
100
150
200
250
TIME (MINUTES)

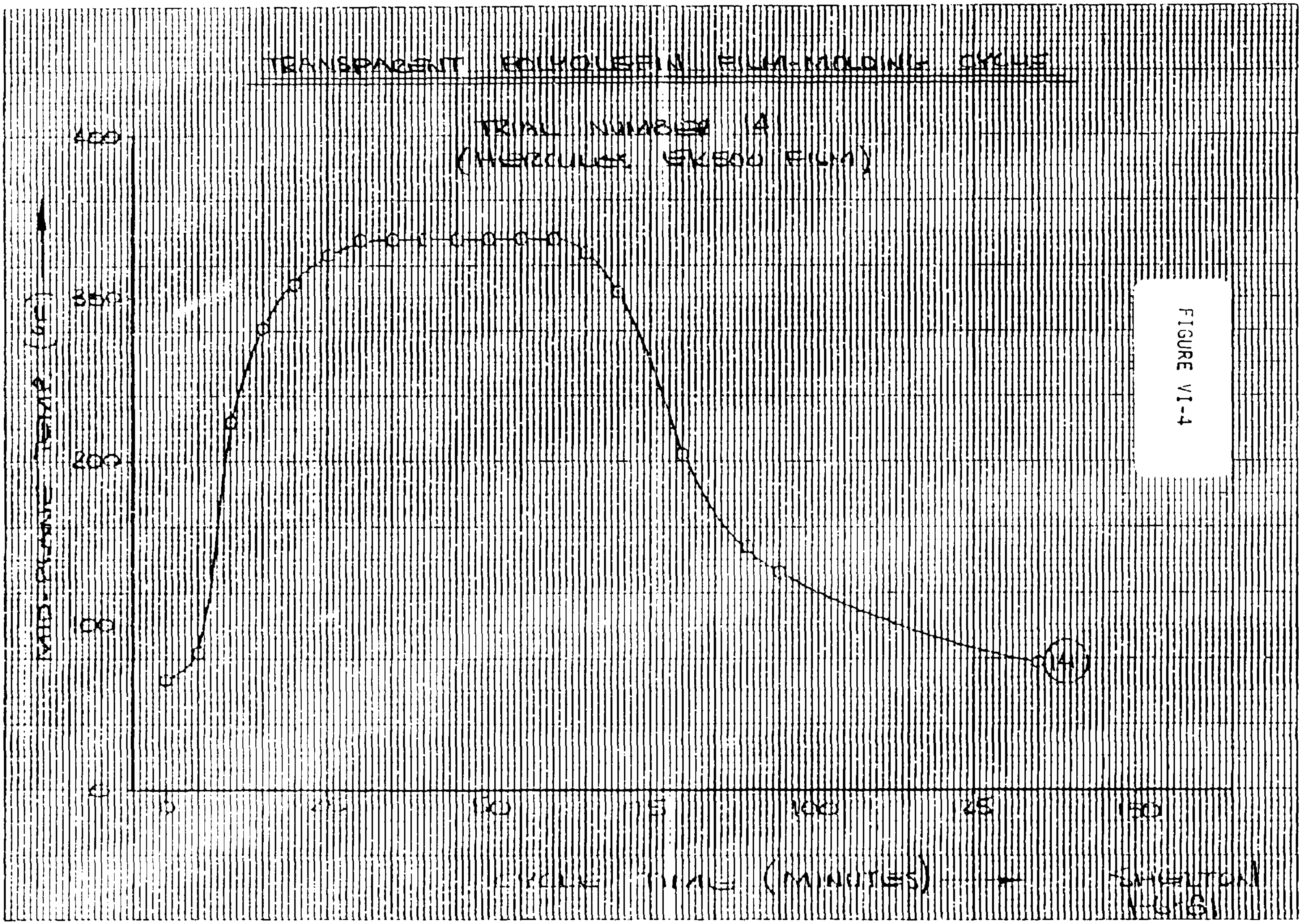


FIGURE VI-4

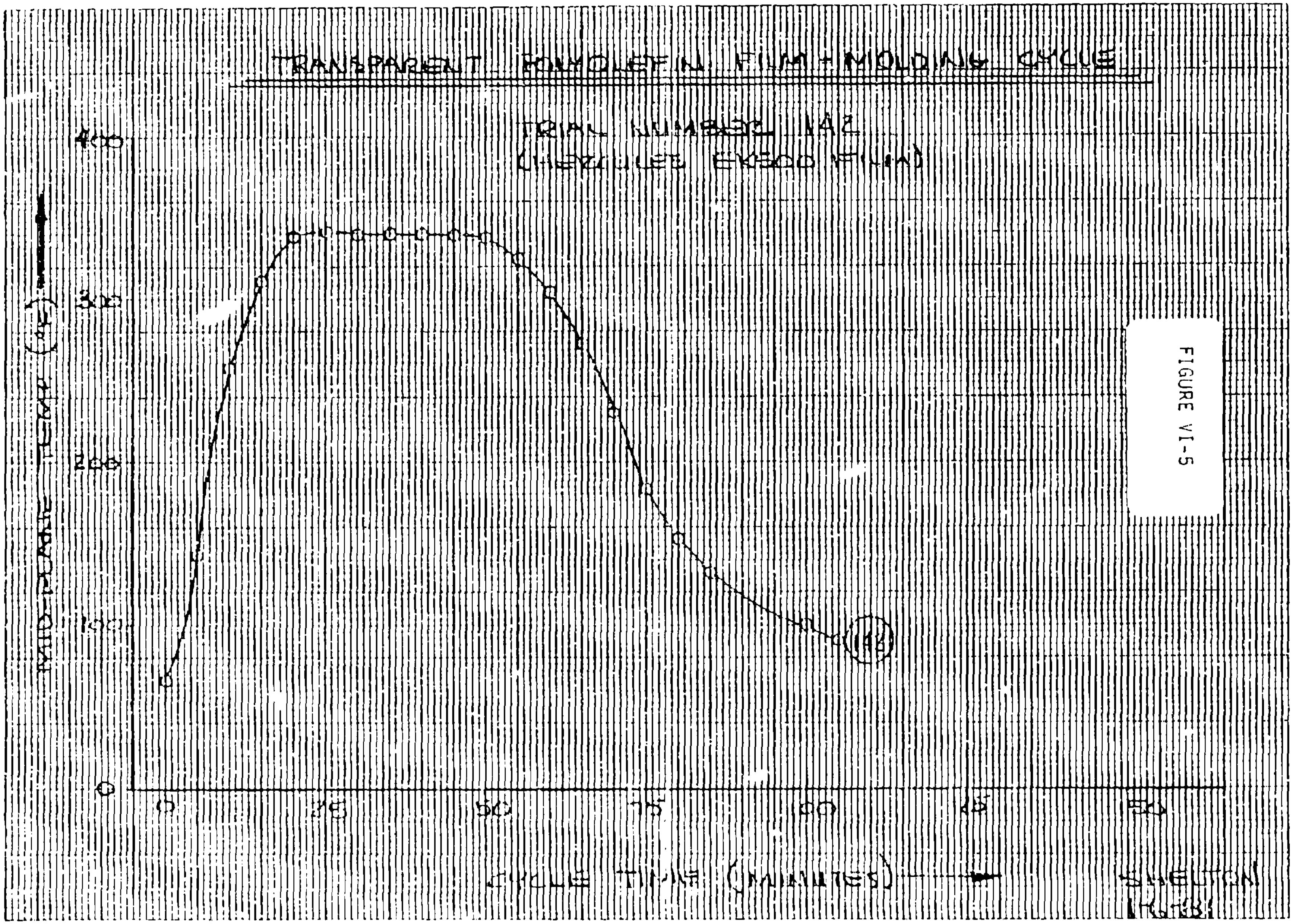

TRANSPARENT POLYOLEFIN FILM + MOLDING CYCLE
TRIAL NUMBER 142
400
300
200
100
0
0
25
50
75
100
125
150
CYCLE TIME (MINUTES)
SHELTON

FIGURE VI-5

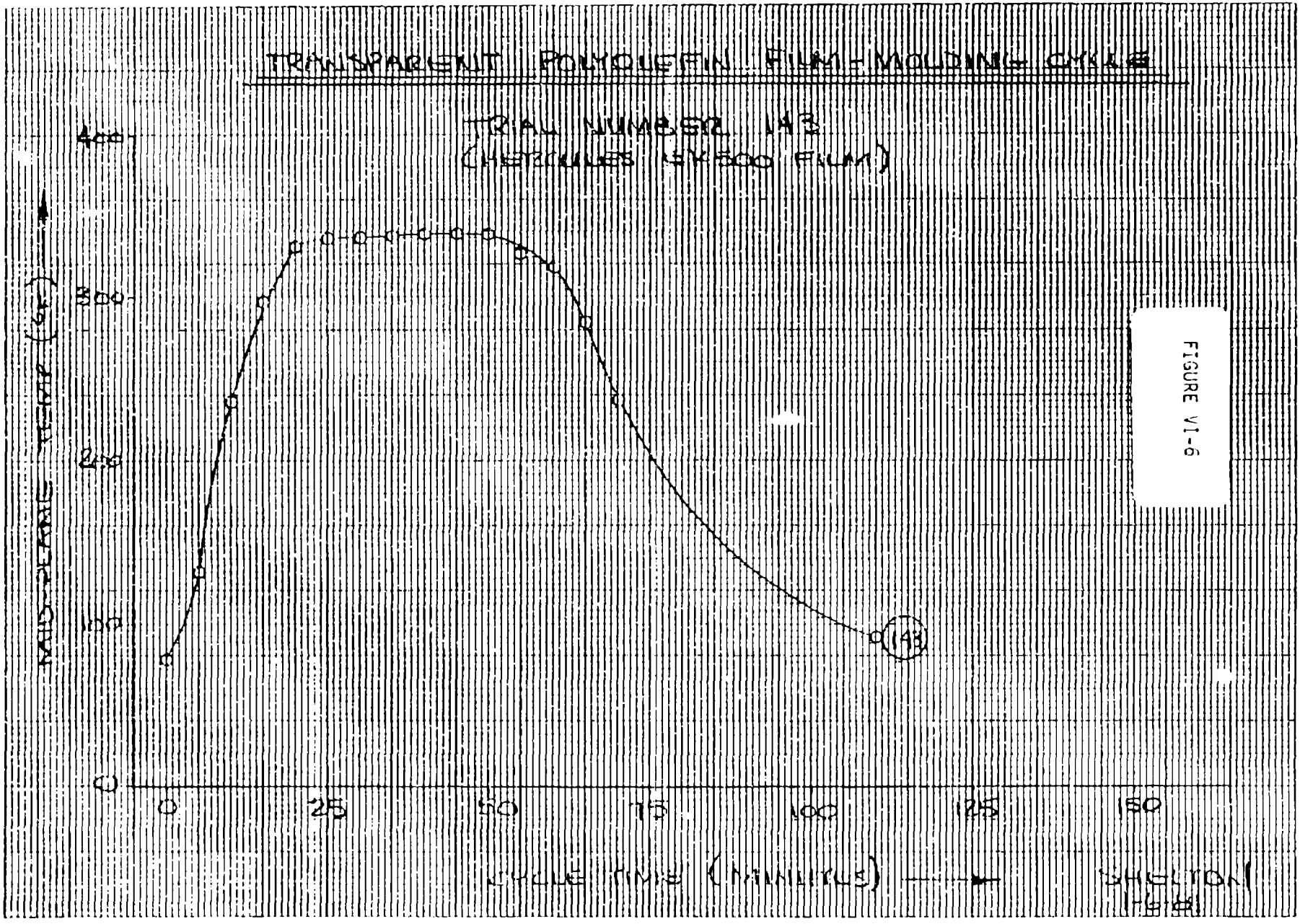

TRANSPARENT POLYOLEFIN FILM-MOULDING CYCLE
TRIAL NUMBER 143
(HERCULES EX-300 FILM)
MAXIMUM STRAIN (%)
400
200
100
0
0
25
50
75
100
125
150
CYCLE TIME (MINUTES)
(43)

FIGURE VI-6

FIGURE VI-7

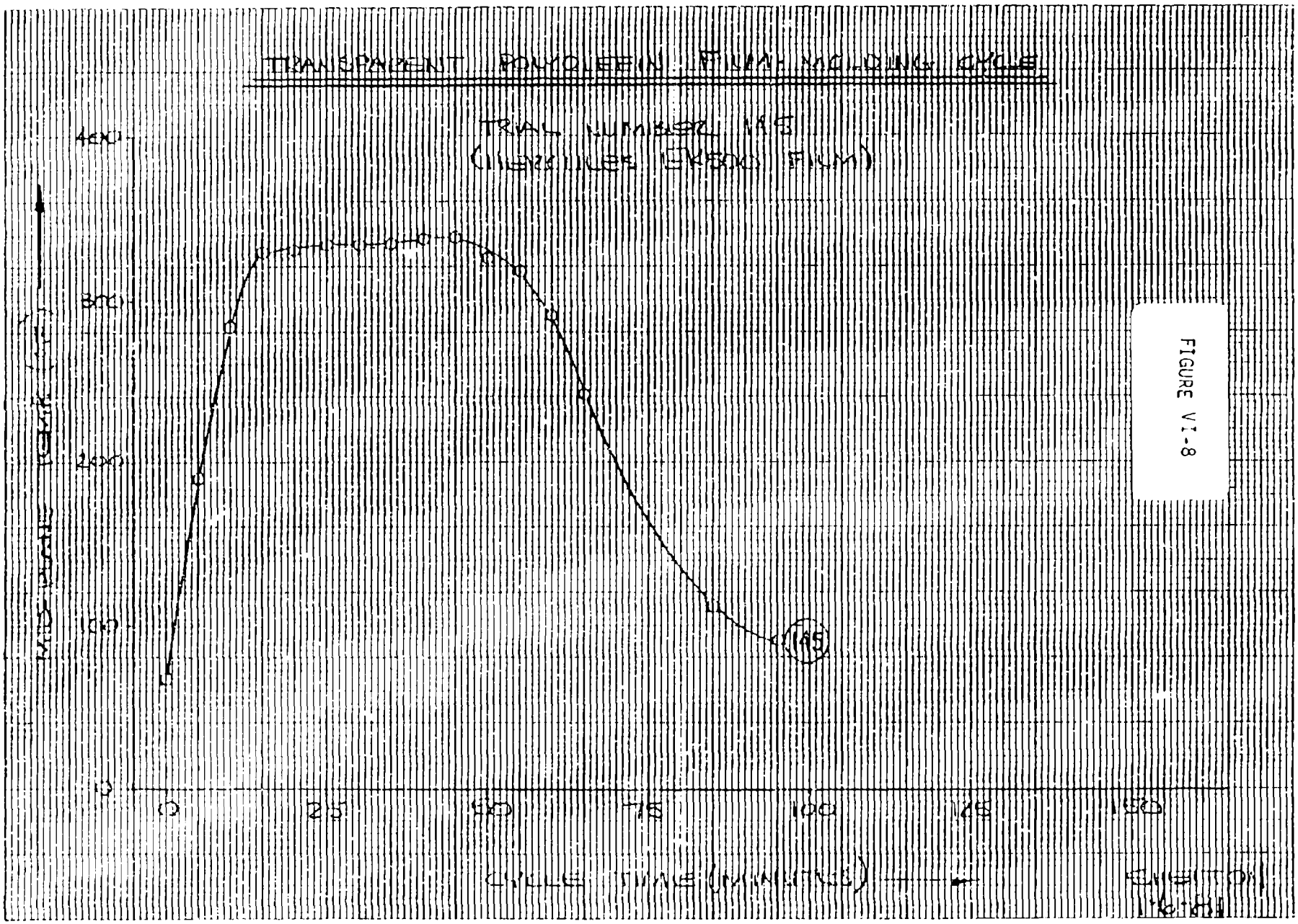

TRANSPARENT POLYOLEFIN FILM MIL-O-NIK CYCLE
TRIAL NUMBER 143
(HUMIDITY EXPOSED FILM)
4000
3000
2000
1000
0
0
25
50
75
100
125
150
(145)

FIGURE VI-8

FIGURE VI-9

FIGURE VI-10

FIGURE VI-11

TRANSPARENT CONDUCTIVE FILM: MOLDING CYCLES
TRIAL MOLDING OF 48 CAVITY MOLD
(48)
Cycle time (sec)
Mold-surface temp (°F)

FIGURE VI-12

FIGURE VI-13

FIGURE VI-14

46 1323

FIGURE VI-15

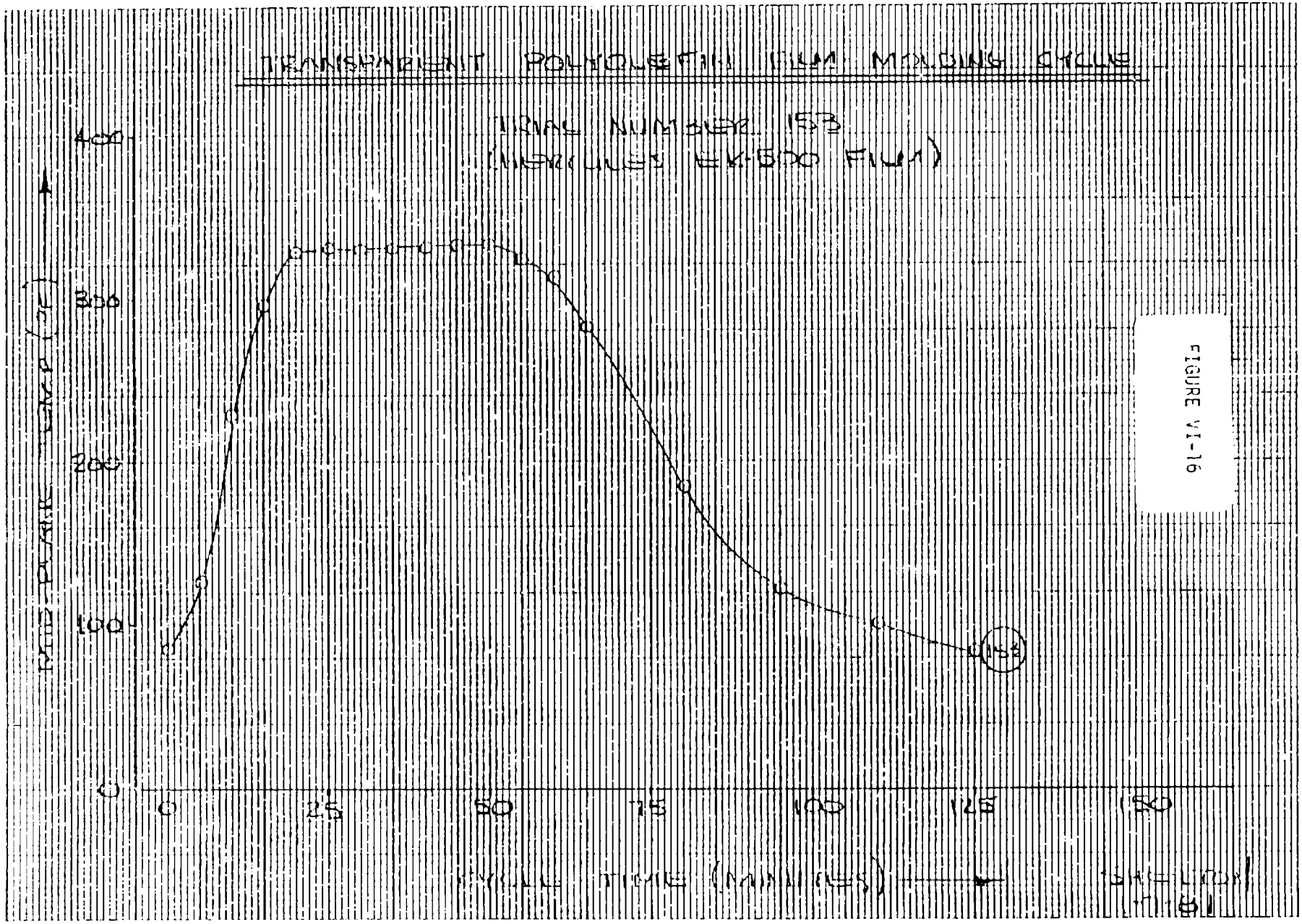

TRANSIENT POWER FILM MELTING CYCLE
TRIAL NUMBER 153
(MECHANICALLY ENERGIZED FILM)
400
300
200
100
0
0
25
50
75
100
125
150

FIGURE VI-16

FIGURE VI-17

FIGURE VI-18

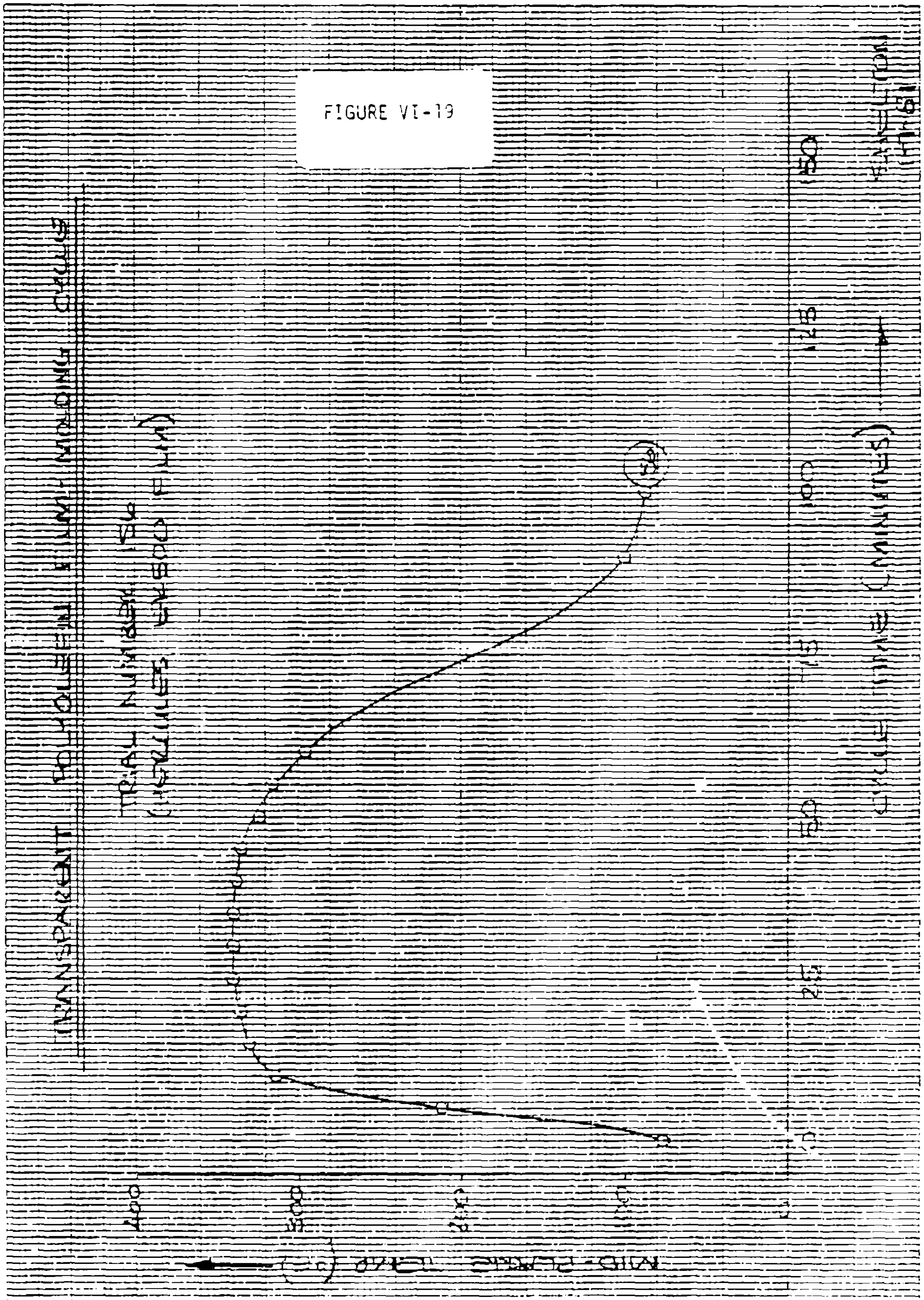

TRANSPARENT POLYOLEFIN FILM MOLDING CYCLE
TRIAL NUMBER 56
CYCLE TIME (MINUTES)
MID-PLATE TEMP (°C)
0
25
50
75
100
125
150
100
200
300
400

FIGURE VI-19

APPENDIX C

INDIVIDUAL LIGHT TRANSMISSION AND HAZE READINGS

TASK I - Trial Number 14

TASK II - Trial Numbers 17 through 73

TASK III - Trial Numbers 74 through 120

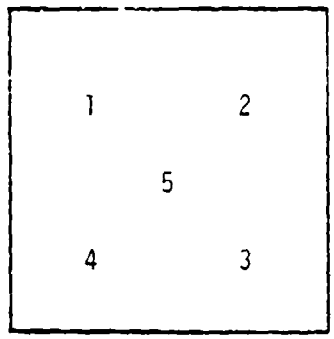
TASK IV - Trial Numbers 121 through 137

TASK VI - Trial Numbers 138 and 139

TASK I

LIGHT TRANSMISSION AND HAZE
TESTING AT +75°F PER ASTM D-1003

Trial Number	Film		Location of Readings 1	2	3	4	5
14	N400	L.T. (%)	37.0	37.7	35.1	40.0	29.9
		Haze (%)	78.2	74.9	80.4	76.2	78.5



Location of Readings

TASK II

LIGHT TRANSMISSION AND HAZE

TESTING AT +75°F PER ASTM D-1003

Trial Number	Film		Location of Readings 1	2	3	4	5
17	B-503	L.T. (%)	89.2	83.6	85.5	86.4	85.7
		Haze (%)	6.2	4.7	7.8	4.2	3.7
18	B-503	L.T. (%)	86.4	84.7	87.5	86.5	86.1
		Haze (%)	4.4	4.1	4.6	4.2	4.0
19	B-503	L.T. (%)	86.4	85.5	86.1	85.7	86.7
		Haze (%)	3.0	3.5	4.3	3.0	3.0
20	N600(AC)	L.T. (%)	90.3	88.8	94.2	88.8	89.1
		Haze (%)	5.7	5.6	4.3	6.5	5.1
21	N600(AC)	L.T. (%)	89.2	89.0	88.7	87.6	91.3
		Haze (%)	8.3	8.1	7.7	7.1	4.9
22	AT 61	L.T. (%)	69.6	63.7	73.5	71.2	67.9
		Haze (%)	43.8	46.2	39.5	38.7	42.9
23	N600(AC)	L.T. (%)	88.4	88.5	89.3	88.7	89.0
		Haze (%)	6.6	7.5	5.7	6.1	4.9
24	N600(AC)	L.T. (%)	87.2	88.9	88.9	89.5	90.1
		Haze (%)	1.4	6.2	6.1	5.1	6.3
25	N600(R) (1)	L.T. (%)	25.5	22.8	20.9	17.2	19.0
		Haze (%)	100	97.1	98.1	96.4	100
26	N600(R) (1)	L.T. (%)	35.2	35.2	29.0	23.3	25.3
		Haze (%)	90.8	76.6	86.8	77.7	79.9
27	N600(R) (1)	L.T. (%)	38.1	38.7	27.7	21.7	28.3
		Haze (%)	88.0	81.6	73.6	81.8	75.2
28	AT 61	L.T. (%)	68.0	69.5	73.5	75.2	73.2
		Haze (%)	41.6	39.9	39.4	37.6	38.5
29	AT 61	L.T. (%)	69.5	72.9	73.8	74.7	70.4
		Haze (%)	40.9	37.8	34.8	34.9	38.4
30	P 2102	L.T. (%)	81.2	83.2	80.7	80.9	80.8
		Haze (%)	23.4	23.0	25.9	25.4	25.3
31	P 2102	L.T. (%)	79.3	81.7	80.7	79.7	80.8
		Haze (%)	25.0	23.8	26.2	26.9	24.7
32	P 2102	L.T. (%)	78.6	81.1	80.1	79.6	80.0
		Haze (%)	23.3	23.9	24.5	24.5	26.5
33	P 2102	L.T. (%)	79.4	80.0	80.8	80.6	81.0
		Haze (%)	23.8	23.7	24.5	23.1	24.0

LIGHT TRANSMISSION AND HAZE TESTING

Trial Number	Film		Location of Readings 1	2	3	4	5
34	AT-61	L.T. (%)	74.0	72.9	72.7	74.5	72.7
		Haze (%)	33.7	34.9	35.9	35.2	36.2
35	AT-61	L.T. (%)	73.0	72.9	67.4	66.4	67.7
		Haze (%)	35.1	36.1	38.3	37.6	42.2
36	G.E.	L.T. (%)	80.7	80.0	81.4	79.6	80.7
		Haze (%)	8.4	9.1	8.6	8.4	8.3
37	X-207	L.T. (%)	78.0	79.4	78.3	78.4	80.4
		Haze (%)	5.5	4.8	5.4	5.3	5.9
38	P-81B	L.T. (%)	74.0	72.2	72.0	72.3	71.5
		Haze (%)	6.6	8.1	8.5	7.4	10.8
39	X-207	L.T. (%)	76.8	77.8	77.1	76.1	78.4
		Haze (%)	6.3	6.3	7.5	6.9	7.6
40	G.E.	L.T. (%)	80.6	82.3	80.5	81.2	82.2
		Haze (%)	6.5	5.4	6.9	6.8	8.3
41	B-500	L.T. (%)	83.8	83.2	82.9	84.0	83.5
		Haze (%)	3.4	4.0	3.8	3.4	4.2
42	N-400 II (2)	L.T. (%)	87.5	86.8	87.0	86.4	87.3
		Haze (%)	15.3	12.2	16.8	14.8	11.2
43	P-81-B	L.T. (%)	72.7	73.1	72.6	73.2	73.5
		Haze (%)	9.8	9.2	8.6	10.5	10.4
44	B-500	L.T. (%)	82.7	82.7	82.9	83.0	83.0
		Haze (%)	4.8	4.2	4.3	4.1	5.2
45	N-400, II (2)	L.T. (%)	86.2	87.4	87.3	86.4	86.6
		Haze (%)	23.5	17.8	14.8	15.7	22.0
46	Capacitor	L.T. (%)	80.6	80.4	80.2	79.6	80.2
		Haze (%)	4.2	4.9	4.2	4.8	4.4
47	N-400, II (2)	L.T. (%)	88.2	87.4	87.5	88.2	88.1
		Haze (%)	23.2	24.9	20.9	21.1	25.5
48	B-500	L.T. (%)	83.3	82.9	82.4	82.4	82.5
		Haze (%)	4.2	4.0	4.4	4.3	3.9
49	P-81-B	L.T. (%)	73.7	72.7	72.5	73.1	72.9
		Haze (%)	7.8	8.2	8.6	8.1	7.9
50	X-207	L.T. (%)	81.6	80.6	79.2	79.8	79.8
		Haze (%)	6.3	6.9	7.4	7.4	6.3
51	N400, II (2)	L.T. (%)	84.1	85.2	85.7	85.1	84.6
		Haze (%)	24.3	22.3	20.0	23.3	26.5

TASK II - Cont Page 3

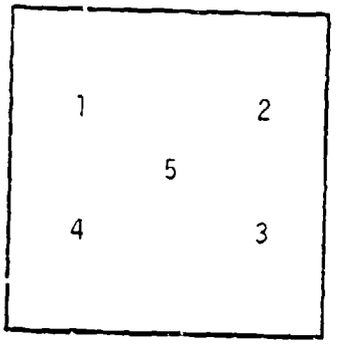
LIGHT TRANSMISSION AND HAZE TESTING

Trial Number	Film		Location of Readings 1	2	3	4	5
52	N-400, II (2)	L.T. (%)	87.5	87.4	85.3	87.0	86.9
		Haze (%)	19.6	23.2	28.1	21.9	24.0
53	B-500	L.T. (%)	84.1	83.7	84.0	84.1	84.0
		Haze (%)	3.3	4.3	3.5	3.6	3.3
54	SK-300	L.T. (%)	88.0	87.9	86.2	88.2	88.1
		Haze (%)	7.0	9.2	10.8	7.5	8.0
55	SK-300	L.T. (%)	86.3	86.7	85.4	87.2	86.0
		Haze (%)	8.5	9.4	8.3	7.7	8.0
56	SK-300	L.T. (%)	39.7	37.7	37.3	37.4	38.5
		Haze (%)	99.0	100.0	100.0	99.0	99.0
57	SK-300	L.T. (%)	65.0	66.8	69.5	67.6	68.3
		Haze (%)	25.2	27.3	24.5	26.3	24.5
58	SK-300	L.T. (%)	82.3	83.6	81.8	82.7	82.1
		Haze (%)	11.4	12.5	14.5	13.8	12.7
59	SK-300	L.T. (%)	83.0	82.4	83.1	83.8	82.6
		Haze (%)	7.3	8.0	6.7	7.6	6.9
60	SK-300	L.T. (%)	83.8	84.2	83.3	84.8	84.5
		Haze (%)	6.2	5.8	6.7	6.1	6.6
61	SK-300	L.T. (%)	83.3	83.8	84.1	83.6	84.0
		Haze (%)	6.8	6.0	7.5	8.3	7.1
62	SK-300	L.T. (%)	86.0	85.1	83.9	85.8	87.1
		Haze (%)	7.0	7.7	7.9	7.8	7.8
63	El Rexene	L.T. (%)	90.3	90.0	87.7	91.0	91.5
		Haze (%)	13.5	15.2	18.5	16.1	15.0
64	Dia. Shamrock	L.T. (%)	33.5	43.0	32.2	20.7	42.7
		Haze (%)	73.6	73.6	73.6	73.6	73.6
65	Dia. Shamrock	L.T. (%)	41.5	38.5	39.0	37.3	32.5
		Haze (%)	35.4	39.4	44.1	40.4	44.4
66	Dia. Shamrock	L.T. (%)	0	0	10.5	21.2	0
		Haze (%)	69.4	69.1	61.7	53.6	71.6
67	El Rexene	L.T. (%)	-	91.5	-	-	-
		Haze (%)	-	14.7	-	-	-
68	Dia. Shamrock	L.T. (%)	0	0	0	0	0
		Haze (%)	71.4	70.6	71.5	71.1	67.4
69	El Rexene	L.T. (%)	91.3	92.0	91.5	88.8	89.5
		Haze (%)	12.3	11.2	14.7	13.5	18.4

LIGHT TRANSMISSION AND HAZE TESTING

Trial Number	Film		Location of Readings 1	2	3	4	5
70	EK-500	L.T. (%)	89.8	87.7	88.0	87.7	87.2
		Haze (%)	1.5	0	1.3	0	0.6
71	EK-500	L.T. (%)	87.7	88.3	88.5	88.8	87.5
		Haze (%)	1.8	2.6	2.6	2.6	3.6
72	El Rexene	L.T. (%)	58.8	55.2	54.7	57.5	60.0
		Haze (%)	38.8	43.0	44.0	43.4	38.2
73	EK-500	L.T. (%)	84.8	85.8	85.7	86.7	85.0
		Haze (%)	3.7	3.4	4.4	5.2	8.6

(1) Film identified as N600 (R), oriented by Revere, is N400
(2) Suspected to be N600 film



Location of Readings

TASK III

LIGHT TRANSMISSION AND HAZE
TESTING AT +75°F PER ASTM D-1003
(HERCULES EK-500 FILM)

Trial Number		Location of Reading 1	2	3	4	5
74 (Hazy Area)	L.T. (%)	83.4	79.3	81.3	78.2	79.6
	Haze (%)	6.3	21.8	23.2	25.4	20.6
74 (Clear Area)	L.T. (%)	82.7	83.4	83.2	82.7	83.3
	Haze (%)	5.7	4.4	5.0	4.1	4.5
75	L.T. (%)	83.3	82.1	81.1	80.9	80.5
	Haze (%)	5.7	5.5	4.4	3.3	3.3
76	L.T. (%)	82.0	81.2	82.7	83.8	80.6
	Haze (%)	5.8	3.9	5.1	5.3	2.6
77	L.T. (%)	83.2	83.7	84.1	83.0	81.6
	Haze (%)	4.2	4.7	5.4	4.4	2.4
78	L.T. (%)	82.4	84.3	83..	82.7	82.1
	Haze (%)	4.3	4.1	4.0	4.5	4.5
79	L.T. (%)	83.3	83.9	82.5	83.5	82.9
	Haze (%)	4.5	5.3	5.1	5.8	4.8
80	L.T. (%)	85.3	86.2	86.2	86.0	84.3
	Haze (%)	4.0	5.1	4.2	5.0	3.1
81	L.T. (%)	84.2	84.8	84.3	83.2	81.9
	Haze (%)	4.5	5.2	5.2	4.6	2.3
82	L.T. (%)	58.4	51.2	55.6	49.7	51.2
	Haze (%)		High Haze - Not Measured			
83	L.T. (%)	83.9	84.1	84.2	84.4	82.6
	Haze (%)	5.4	5.1	5.6	5.0	2.8
84	L.T. (%)	83.0	84.4	83.6	82.8	82.3
	Haze (%)	5.4	6.7	4.8	3.9	3.3
85	L.T. (%)	80.7	81.3	80.6	81.3	80.0
	Haze (%)	3.4	4.6	6.4	4.9	3.0
86	L.T. (%)	79.1	79.3	79.1	78.9	78.5
	Haze (%)	6.4	7.7	5.6	7.5	6.7
87	L.T. (%)	85.1	84.1	85.3	86.3	83.6
	Haze (%)	4.8	5.9	7.0	6.4	2.6
88	L.T. (%)	83.9	84.1	84.7	85.0	82.3
	Haze (%)	6.7	7.3	6.1	5.2	2.7
89	L.T. (%)	82.1	78.8	77.9	79.7	77.3
	Haze (%)	5.2	8.5	7.8	8.2	5.2

LIGHT TRANSMISSION AND HAZE

(HERCULES EK-500 FILM)

Trial Number		Location of Reading 1	2	3	4	5
90	L.T. (%)	62.7	72.6	60.0	33.0	60.6
	Haze (%)	19.7	6.5	26.7	92.8	26.0
91	L.T. (%)	83.3	82.3	82.1	82.7	80.6
	Haze (%)	8.0	5.5	3.9	4.7	2.8
92	L.T. (%)	Caul Plate Left Off				
	Haze (%)	L.T. and Haze not measured				
93	L.T. (%)	57.4	54.7	64.1	79.0	61.7
	Haze (%)	69.0	74.8	42.2	8.7	51.0
94	L.T. (%)	84.5	83.8	83.2	83.2	81.8
	Haze (%)	5.2	6.0	5.6	5.7	3.3
95	L.T. (%)	83.1	83.2	82.9	83.0	81.6
	Haze (%)	4.3	4.5	4.4	4.2	2.9
96	L.T. (%)	83.8	84.3	83.5	84.3	82.4
	Haze (%)	4.6	4.0	4.2	4.2	2.4
97	L.T. (%)	82.5	82.4	81.4	81.3	80.1
	Haze (%)	7.0	6.0	4.7	4.5	2.8
98	L.T. (%)	64.6	55.5	57.1	65.2	57.7
	Haze (%)	60.1	82.7	88.6	51.7	72.6
99	L.T. (%)	74.5	74.0	74.0	75.3	72.3
	Haze (%)	6.4	7.0	6.5	7.3	6.6

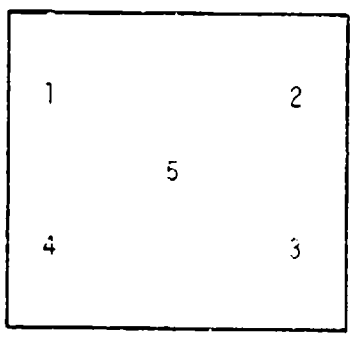
LIGHT TRANSMISSION AND HAZE

(HERCULES EK-500 FILM)

LOCATION OF LIGHT TRANSMISSION

AND HAZE READINGS

(PANELS 74-99)



LIGHT TRANSMISSION AND HAZE

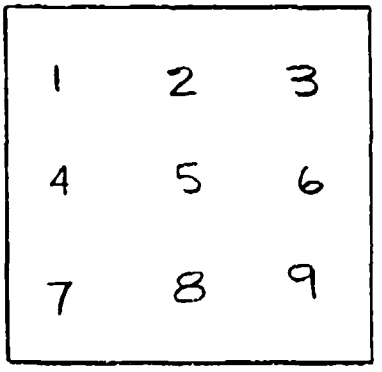
(HERCULES EK-500 FILM)

PANEL NUMBER		LOCATION OF READING 1	2	3	4	5	6	7	8	9
100	LT=	82.1	72.3	75.9	82.8	74.6	74.3	83.3	75.5	78.2
	H=	4.5	9.1	5.1	3.1	7.0	4.9	2.5	3.7	4.1
101	LT=	83.4	78.0	77.6	82.6	75.6	74.3	80.5	76.0	75.2
	H=	4.1	6.3	6.7	3.7	6.2	5.8	3.8	4.6	5.4
102	LT=	84.9	82.7	83.5	82.7	80.1	79.6	82.3	79.5	79.6
	H=	5.1	6.4	6.8	4.6	3.6	3.5	4.8	3.9	4.0
103	LT=	84.4	82.2	81.6	84.5	80.1	80.9	84.1	81.7	81.4
	H=	4.5	4.4	4.6	4.0	3.1	3.5	2.7	2.1	2.7
104	LT=	82.7	79.7	79.4	82.0	78.6	79.0	82.9	79.0	79.6
	H=	5.0	4.4	4.6	4.2	3.9	4.2	4.7	3.6	3.0
105	LT=	83.3	80.5	79.3	81.9	78.5	78.5	82.0	78.9	79.5
	H=	5.7	4.8	5.4	4.3	3.9	4.4	3.9	3.4	2.4
106	LT=	82.7	79.3	79.4	82.1	77.8	78.0	82.3	79.0	78.7
	H=	4.6	5.7	5.6	4.1	4.4	3.9	3.8	3.2	4.5
107	LT=	85.0	84.2	84.6	82.9	81.1	83.5	83.0	82.6	82.8
	H=	5.0	4.3	4.7	10.6	11.9	5.3	7.7	5.8	3.0
108	LT=	81.7	79.3	79.3	82.4	80.4	80.7	83.4	83.4	86.2
	H=	14.6	25.7	25.5	18.7	21.5	22.0	4.7	4.0	5.0
109	LT=	84.3	82.6	85.2	83.3	82.9	85.0	81.3	83.4	86.7
	H=	4.6	8.3	4.5	9.7	3.8	2.6	12.9	5.4	3.3
110	LT=	82.7	82.7	81.3	68.3	62.7	72.6	71.2	66.4	74.0
	H=	4.3	4.5	4.8	49.7	91.3	14.0	4.7	30.1	9.5
111	LT=	84.2	79.9	79.0	78.1	77.5	79.0	84.7	79.6	80.5
	H=	3.7	3.6	4.7	3.4	3.5	3.8	4.3	4.0	5.9
112	LT=	83.0	81.0	79.7	82.7	80.5	80.6	84.4	83.7	83.5
	H=	4.9	4.0	4.0	2.5	2.4	3.3	2.2	1.6	2.8
113	LT=	85.1	83.6	75.5	75.1	74.6	74.2	78.3	73.5	72.2
	H=	5.6	4.1	45.2	43.2	55.5	48.7	21.0	63.9	58.9
114	LT=	83.6	84.6	83.0	77.1	75.8	80.5	84.9	83.1	84.4
	H=	4.9	2.9	3.4	49.1	56.6	27.4	3.8	7.1	3.6
115	LT=	83.8	82.5	81.4	84.0	81.8	82.0	86.9	82.6	83.5
	H=	3.8	3.4	3.7	2.7	1.7	3.0	2.4	0.9	1.9

LIGHT TRANSMISSION AND HAZE
(HERCULES EK-500 FILM)

PANEL NUMBER		LOCATION OF READING 1	2	3	4	5	6	7	8	9
116	LT=	86.0	82.7	82.8	85.8	82.1	82.1	84.9	82.2	82.7
	H=	4.6	3.0	4.0	3.6	2.9	3.8	2.9	2.2	3.6
117	LT=	84.3	83.5	84.6	83.2	82.3	84.4	83.4	82.8	83.3
	H=	4.5	3.9	2.6	3.4	2.6	3.3	3.3	2.1	1.4
118	LT=	85.9	84.8	85.3	84.5	82.7	84.0	84.0	84.0	84.7
	H=	5.6	5.2	6.7	4.5	2.5	4.7	4.5	3.3	3.7
119	LT=	84.3	81.9	84.1	84.2	81.6	83.4	85.0	84.4	84.5
	H=	4.3	3.2	4.8	4.3	2.6	4.0	4.9	3.4	2.9
120	LT=	84.5	83.7	84.8	83.9	81.8	84.6	81.7	82.7	84.7
	H=	4.4	2.8	4.8	3.5	2.3	3.6	3.4	3.1	3.6

LOCATION OF LIGHT TRANSMISSION
AND HAZE READINGS
(PANELS 100 - 120)



TASK IV

LIGHT TRANSMISSION AHD HAZE

TESTING AT +75°F PER ASTM D-1003

(HERCULES EK-500 FILM)

LOCATION OF READING

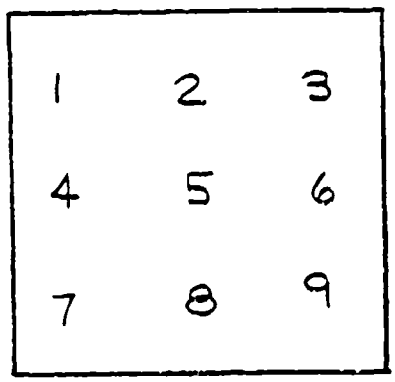
Panel Number		1	2	3	4	5	6	7	8	9
121	LT =	78.1	79.0	79.9	77.0	76.7	78.6	77.2	77.3	79.0
	H =	33.5	30.2	26.8	35.6	37.1	30.5	34.4	32.6	30.3
122	LT =	81.7	80.5	79.7	80.5	79.6	79.6	80.3	80.2	79.7
	H =	28.1	28.7	31.9	30.1	29.7	30.2	28.8	27.8	31.0
123	LT =	85.1	84.1	83.5	85.0	83.6	83.2	8[illegible].4	84.1	83.9
	H =	3.9	4.0	3.8	3.0	3.3	3.6	3.4	3.4	3.2
124	LT =	84.2	83.6	82.9	83.4	82.5	82.2	83.2	82.2	82.0
	H =	12.2	13.7	16.1	13.2	14.6	14.5	14.1	14.2	15.2
125	LT =	83.4	82.8	83.3	83.6	83.0	84.2	84.2	83.3	83.5
	H =	3.2	3.1	2.9	2.8	2.7	2.5	2.6	2.6	2.5
125	LT =	81.1	80.5	80.6	81.7	80.8	81.3	82.9	82.5	82.5
	H =	14.5	14.9	14.9	15.2	14.9	16.9	12.4	13.7	13.0
127	LT =	86.8	85.2	85.4	86.0	83.2	83.0	86.0	84.0	83.8
	H =	6.5	6.6	6.9	6.1	6.3	7.6	6.5	6.3	7.3
128	LT =	86.1	84.2	84.5	85.7	82.8	83.5	85.9	83.7	85.7
	H =	3.3	3.7	4.3	3.3	4.0	3.7	4.7	4.2	4.7
129	LT =	85.8	84.2	85.0	85.3	82.7	83.5	83.9	83.5	85.7
	H =	3.1	4.1	3.7	3.3	3.2	3.0	3.3	3.6	4.2

LIGHT TRANSMISSION AND HAZE

(HERCULES EK-500 FILM)

		LOCATION OF READING								
Panel Number		1	2	3	4	5	6	7	8	9
130	LT =	86.2	83.4	82.6	85.9	82.7	83.4	86.5	84.0	83.0
	H =	3.3	3.5	2.3	3.3	2.4	3.7	3.6	3.5	4.4
131	LT =	86.3	83.6	83.9	86.2	82.6	83.5	84.3	83.2	84.7
	H =	3.6	2.3	3.1	4.1	3.3	3.9	2.5	3.3	4.9
132	LT =	84.5	81.9	82.1	83.8	81.0	83.5	84.9	82.8	84.7
	H =	4.6	5.1	3.8	3.6	6.2	3.6	3.6	3.1	3.7
133	LT =	86.3	85.0	84.5	86.5	84.1	84.1	86.1	84.2	84.4
	H =	3.6	5.2	2.5	3.8	4.8	3.0	3.4	2.7	2.6
134	LT =	84.3	80.4	81.9	84.5	81.6	82.7	85.4	83.4	84.7
	H =	3.8	31.2	8.0	3.1	9.2	4.3	3.1	2.2	4.0
135	LT =	84.8	76.2	83.5	83.5	69.8	80.8	82.9	65.7	70.7
	H =	3.5	19.6	3.2	3.0	38.1	3.2	3.3	41.7	39.5
136	LT =	82.8	72.8	79.6	82.5	75.0	80.7	83.5	81.8	84.4
	H =	3.2	59.2	13.3	4.1	53.3	10.6	3.5	5.0	2.4
137	LT =	83.7	75.3	77.5	83.9	75.4	77.4	84.4	80.3	82.4
	H =	3.0	38.9	15.7	3.1	35.4	16.2	2.9	14.5	3.3

LOCATION OF LIGHT TRANSMISSION AND HAZE READINGS (ALL PANELS)

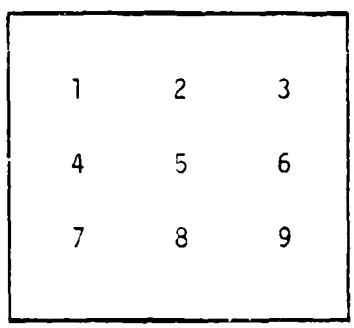


TASK VI

LIGHT TRANSMISSION AND HAZE

TESTING AT +75°F PER ASTM D-1003
(HERCULES EK-500 FILM)

Panel Number		Location of Readings 1	2	3	4	5	6	7	8	9
138 LT	=	86.1	84.4	84.6	85.8	83.2	83.6	85.2	83.8	84.7
H	=	3.4	3.6	4.2	3.2	4.0	3.6	4.3	3.9	4.6
139 LT	=	85.6	84.2	84.0	84.3	82.7	83.5	85.0	84.3	84.3
H	=	5.7	4.4	4.4	4.2	2.4	4.0	4.4	4.2	4.5



Location of Light Transmission and Haze readings.

TASK II

Crown Zellerbach AT-61
Hercules N-400 (Rolled by Am. Can)
Hercules N-600 (Rolled by Revere) (Is N400 Film)
Hercules N-600 (Rolled by Am. Can)
Hercules B-503
Toyoba P2102
Cryovac X-207
Hercules N-400, Type II (Suspected to be N600 Film)
Mobil Bicor 240-B1 (P-81-B)
General Electric Capacitor Grade
Hercules B-500
Trea SK 300-2
Diamond Shamrock NB-81-59-3
Hercules EK-500
El Rexene PP-41-6300-4153

AETL

APPROVED ENGINEERING TEST LABORATORIES / 1536 EAST VALENCIA / FULLERTON, CALIFORNIA 92631 / TEL. (714) 879-6110

A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1399-1
P.O. No. 21898
Date: 7 September 1976

Attention: R. Shelton

1.0 TEST SAMPLE

One Plastic Film Material marked Crown Zellerbach #AT-61 (Comp. rolled by American Can Co. at 230°F)

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70

3.0 TEST RESULTS

3.1 Tested Parrallel To Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	250	593	(See Note 1)
2	250	567	(See Note 1)
3	250	579	(See Note 1)
4	250	525	(See Note 1)
5	250	498	(See Note 1)
Average		552	

3.2 Test Perpendicular to Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	250	Nil	(See Note 2)
2	250	Nil	(See Note 2)
3	250	Nil	(See Note 2)
4	250	Nil	(See Note 2)
5	250	Nil	(See Note 2)

Note 1: Specimen returned to about the original shape and dimensions upon cooling to room temperature.

Note 2: No load indication on 0-1 lb. range (1 division = 0.01 lb.)

APPROVED ENGINEERING TEST LABORATORIES

Francis Pickell, Sr.
Francis Pickell Sr., Project Engineer

Subscribed and sworn to before me this 3rd day of October 29, 1976.

OFFICIAL SEAL
BETTY MATTESON
NOTARY PUBLIC - CALIFORNIA
ORANGE COUNTY
My Commission Expires Oct. 29, 1977

Betty Matteson
Betty Matteson, Notary Public in and for the County of Orange, State of California. My commission expires October 29, 1977.

dkl

APPROVED ENGINEERING TEST LABORATORIES

Note 1: Specimen returned to about the original shape and dimensions upon cooling to room temperature.

Note 2: No load indication on 0-1 lb. range (1 division = 0.01 lb.)

APPROVED ENGINEERING TEST LABORATORIES

Francis Pickell, Sr.
Francis Pickell Sr., Project Engineer

Subscribed and sworn to before me this 3rd day of October 29, 1976.

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Betty Matteson, Notary Public in and for the County of Orange, State of California. My commission expires October 29, 1977.

dkl

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APPROVED ENGINEERING TEST LABORATORIES / 1536 EAST VALENCIA / FULLERTON, CALIFORNIA 92631 / TEL. (714) 879-6110
A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1399-2
P.O. No. 21898
Date: 7 September 1976

Attention: R. Shelton

1.0 TEST SAMPLE

One Plastic Film Material marked Hercules N400 (Comp. rolled by American Can Co. at 244°F).

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70

3.0 TEST RESULTS

3.1 Tested Parrallel To Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	250	800	(See Note 1)
2	250	911	(See Note 1)
3	250	811	(See Note 1)
4	250	835	(See Note 1)
5	250	835	(See Note 1)
Average		838	

3.2 Test Perpendicular to Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	250	Nil	(See Note 2)
2	250	Nil	(See Note 2)
3	250	Nil	(See Note 2)
4	250	Nil	(See Note 2)
5	250	Nil	(See Note 2)

OTHER DIVISIONS

LOS ANGELES DIVISION / 5370 WEST 104TH STREET / LOS ANGELES CALIFORNIA 90045 / (213) 776 3702
VALLEY DIVISION / 9551 CANOGA AVENUE / CHATSWORTH CALIFORNIA 91311 / (213) 341 0830
SAUGUS DIVISION / 20988 W. GOLDEN TRIANGLE RD. / SAUGUS CALIFORNIA 91350 / (805) 259 8184
CALIFORNIA TEST LABS DIV / 3422 POTRERO AVE / SO. EL MONTE CA 91733 / (213) 283 8465
SO. EL MONTE DIV. / 3431 POTRERO AVENUE / SO. EL MONTE CALIFORNIA 91733 / (213) 444 9511

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A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1399-3
P.O. No. 21898
Date: 7 September 1976

Attention: R. Shelton

1.0 TEST SAMPLE

One Plastic Film Material marked Hercules N600 (Comp. rolled by Revere)

2.0 TEST PERFORMED

NOTE: Film identified as N600 Revere, is N400

Orientation Release Stress per ASTM D1504-70

3.0 TEST RESULTS

3.1 Tested Parrallel To Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	250	496	(See Note 1)
2	250	506	(See Note 1)
3	250	550	(See Note 1)
4	250	551	(See Note 1)
5	250	541	(See Note 1)
Average		529	

3.2 Test Perpendicular to Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	250	Nil	(See Note 2)
2	250	Nil	(See Note 2)
3	250	Nil	(See Note 2)
4	250	Nil	(See Note 2)
5	250	Nil	(See Note 2)

APPROVED ENGINEERING TEST LABORATORIES

Note 1: Specimen returned to about the original shape and dimensions upon cooling to room temperature.

Note 2: No load indication on 0-1 lb. range (1 division = 0.01 lb.)

APPROVED ENGINEERING TEST LABORATORIES

Francis Pickell Sr.

Francis Pickell Sr., Project Engineer

Subscribed and sworn to before me this 3rd day of October 29, 1976.

OFFICIAL SEAL
BETTY MATTESON
NOTARY PUBLIC - CALIFORNIA
ORANGE COUNTY
My Commission Expires Oct. 29, 1977

Betty Matteson

Betty Matteson, Notary Public in and for the County of Orange, State of California. My commission expires October 29, 1977.

dkl

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APPROVED ENGINEERING TEST LABORATORIES / 1536 EAST VALENCIA / FULLERTON, CALIFORNIA 92631 / TEL. (714) 879-6110

A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1399-4
P.O. No. 21898
Date: 7 September 1976

Attention: R. Shelton

1.0 TEST SAMPLE

One Plastic Film Material marked Hercules N600 (Comp. rolled by American Can Co. at 224°F)

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70

3.0 TEST RESULTS

3.1 Tested Parallel To Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	275	404	(See Note 1)
2	275	360	(See Note 1)
3	275	480	(See Note 1)
4	275	480	(See Note 1)
5	275	450	(See Note 1)
Average		435	

3.2 Test Perpendicular to Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	275	Nil	(See Note 2)
2	275	Nil	(See Note 2)
3	275	Nil	(See Note 2)
4	275	Nil	(See Note 2)
5	275	Nil	(See Note 2)

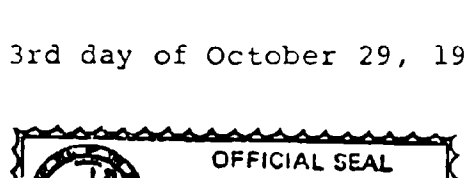
Note 1: Specimen returned to about the original shape and dimensions upon cooling to room temperature.

Note 2: No load indication on 0-1 lb. range (1 division = 0.01 lb.)

APPROVED ENGINEERING TEST LABORATORIES

Francis Pickell, Jr.
Francis Pickell Sr., Project Engineer

Subscribed and sworn to before me this 3rd day of October 29, 1976.



Betty Matteson
Betty Matteson, Notary Public in and for the County of Orange, State of California My commission expires October 29, 1977.

dkl

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APPROVED ENGINEERING TEST LABORATORIES / 1536 EAST VALENCIA / FULLERTON, CALIFORNIA 92631 / TEL. (714) 879-6110
A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1399-5
P.O. No. 21898
Date: 7 September 1976

Attention: R. Shelton

1.0 TEST SAMPLE

One Plastic Film Material marked Hercules B503 (Bi-Axially oriented by Hercules)

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70

3.0 TEST RESULTS

3.1 Tested Parrallel to Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	325	311	(See Note 1)
2	325	316	(See Note 1)
3	325	290	(See Note 1)
4	275	~209	(See Note 2)
5	325	318	(See Note 2)
Average		289	

3.2 Test Perpendicular to Arrow

Specimen No.	Maximum Temperature attained, °F	Release Stress, psi	Remarks
1	325	287	(See Note 1)
2	325	267	(See Note 1)
3	325	221	(See Note 1)
4	295	126	(See Note 2)
5	290	123	(See Note 2)
Average		205	

APPROVED ENGINEERING TEST LABORATORIES

Note 1: Specimen returned to about the original shape and dimensions upon cooling to room temperature.

Note 2: Specimen ruptured upon attainment of maximum release stress.

APPROVED ENGINEERING TEST LABORATORIES

Francis Pickell, Sr.
Francis Pickell Sr., Project Engineer

Subscribed and sworn to before me this 3rd day of October 29, 1976.

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NOTARY PUBLIC - CALIFORNIA
ORANGE COUNTY
My Commission Expires Oct. 29, 1977

Betty Matteson
Betty Matteson, Notary Public in and for the County of Orange, State of California. My commission expires October 29, 1977.

dkl

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A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1738-1
P.O. No. 23437
Date: 17 January 1977

Attention: R. Shelton

1.0 TEST SAMPLE

One plastic Film Material marked Toyoba P-2102.

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70 (*)

3.0 TEST RESULTS

3.1 Test Parallel To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	310	126
2	312	133
3	310	124
4	314	132
5	316	139
Average		131

3.2 Tested Perpendicular To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	314	128
2	312	126
3	310	122
4	312	117
5	318	262(**)
Average		151

(*) Except air medium was used

(**) Two additional specimens were tested, one in same general area as specimen No. 5 and the other one six inches away from specimen No. 5. The results on both tests were simular to the results obtained for specimen No. 5.

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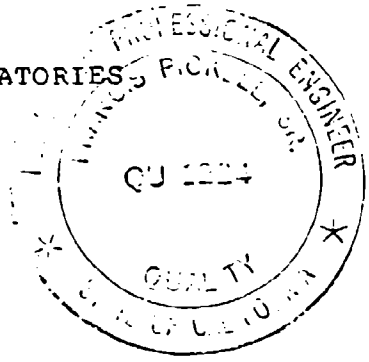
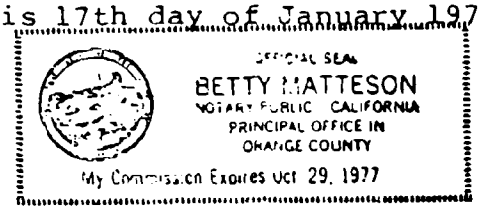


Francis Pickell, Sr.
Francis Pickell Sr., P.E.
Project Engineer

Subscribed and sworn to before me this 17th day of January 1977.



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Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1738-2
P.O. No. 23437
Date: 17 January 1977

Attention: R. Shelton

1.0 TEST SAMPLE

One plastic Film Material marked Cryovac X207.

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70 (*)

3.0 TEST RESULTS

3.1 Test Parallel To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	334	285
2	333	221
3	334	250
4	332	242
5	330	237
Average		247

3.2 Tested Perpendicular To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	280	524
2	273	545
3	276	510
4	274	427
5	274	488
Average		499

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APPROVED ENGINEERING TEST LABORATORIES

(*) Except air medium was used

APPROVED ENGINEERING TEST LABORATORIES

Francis Pickell, Jr.
Francis Pickell Sr., P.E.
Project Engineer

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Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1738-3
P.O. No. 23437
Date: 17 January 1977

Attention: R. Shelton

1.0 TEST SAMPLE

One plastic Film Material marked Hercules N400, Type II.

2.0 TEST PERFORMED NOTE: Film suspected to be N600

Orientation Release Stress per ASTM D1504-70 (*)

3.0 TEST RESULTS

3.1 Test Parallel To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	206	466
2	205	428
3	204	489
4	204	490
5	205	470
Average		469

3.2 Tested Perpendicular To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	250	13
2	260	14
3	262	32
4	260	36
5	262	14
Average		21.8

(*) Except air medium was used

APPROVED ENGINEERING TEST LABORATORIES

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Francis Pickell Sr., P.E.
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REGISTERED PROFESSIONAL ENGINEER
FRANCIS PICKELL SR.
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STATE OF CALIFORNIA

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TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1738-4
P.O. No. 23437
Date: 17 January 1977

Attention: R. Shelton

1.0 TEST SAMPLE

One plastic Film Material marked Mobil Bicor #240-B1.

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70 (*)

3.0 TEST RESULTS

3.1 Test Parallel To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	332	85
2	329	75
3	330	72
4	329	69
5	330	70
Average		74

3.2 Tested Perpendicular To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	326	330
2	328	347
3	324	320
4	326	331
5	326	322
Average		330

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SO. EL MONTE DIV. / 1431 POTRERO AVENUE / SO. EL MONTE, CALIFORNIA 91733 / (213) 444 9513

(*) Except air medium was used

APPROVED ENGINEERING TEST LABORATORIES

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Francis Pickell Sr., P.E.
Project Engineer

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Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1738-5
P.O. No. 23437
Date: 17 January 1977

Attention: R. Shelton

1.0 TEST SAMPLE

One plastic Film Material marked G.E. Capacitor Grade.

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70 (*)

3.0 TEST RESULTS

3.1 Test Parallel To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	325	204
2	328	184
3	326	175
4	327	201
5	326	186
Average		190

3.2 Tested Perpendicular To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	323	331
2	319	323
3	321	331
4	319	311
5	322	323
Average		324

(*) Except air medium was used

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Francis Pickell, Sr.

Francis Pickell Sr., P.E.
Project Engineer

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STATE OF CALIFORNIA

Subscribed and sworn to before me this 17th day of January 1977.

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My Commission Expires Oct 29, 1977

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TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1738-6
P.O. No. 23437
Date: 17 January 1977

Attention: R. Shelton

1.0 TEST SAMPLE

One plastic Film Material marked Hercules B500.

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70 (*)

3.0 TEST RESULTS

3.1 Test Parallel To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	330	295
2	335	288
3	333	288
4	334	290
5	332	281
Average		288

3.2 Tested Perpendicular To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	325	303
2	328	308
3	324	286
4	325	290
5	322	301
Average		298

(*) Except air medium was used

APPROVED ENGINEERING TEST LABORATORIES

Francis Pickell, Jr.
Francis Pickell Sr., P.E.
Project Engineer

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Subscribed and sworn to before me this 17th day of January 1977.

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TESTED FOR

Swedlow, Inc.
12242 Western Ave.
Garden Grove, California 92645

Report No. 677-1738-7
P.O. No. 23437
Date: 17 January 1977

Attention: R. Shelton

1.0 TEST SAMPLE

One plastic Film Material marked Trea SK 300-2

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D1504-70 (*)

3.0 TEST RESULTS

3.1 Test Parallel To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	326	488
2	326	502
3	327	473
4	325	478
5	328	488
Average		486

3.2 Tested Perpendicular To Arrow

Specimen No.	Maximum Temperature Attained, °F	Release Stress, psi
1	316	5.6
2	318	5.6
3	316	5.8
4	316	5.3
5	316	3.4
Average		5.1

(*) Except air medium was used

APPROVED ENGINEERING TEST LABORATORIES

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A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12122 Western Ave.
Garden Grove, California 92642

Report No. 877-3066-1
P.O. No. 31466
Date: 18 September 1978

1.0 TEST ITEM

One Plastic Film Material Marked Diamond Shamock #NB-81-59-3.

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D150420, except air medium was used.

3.0 TEST RESULTS

3.1 Tested Parallel to Direction of Isotrophy

Specimen No.	Maximum Temperature Attained, °F	Orientation Release Stress, psi
1	276	706
2	274	738
3	265	663
4	257	586
5	260	588
Average	266	656

3.2 Tested Normal To Direction of Isotrophy

1	275	1.2
2	273	1.1
3	270	.8
4	272	1.5
5	270	1.2
Average	272	1.2

APPROVED ENGINEERING TEST LABORATORIES

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A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12122 Western Ave.
Garden Grove, California 92642

Report No. 877-3066-2
P.O. No. 31466
Date: 18 September 1978

1.0 TEST ITEM

One Plastic Film Material Marked Hercules #EK500

2.0 TEST PERFORMED

Orientation Release Stress per ASTM D150420, except air medium was used.

3.0 TEST RESULTS

3.1 Tested Parallel to Direction of Isotrophy

Specimen No.	Maximum Temperature Attained, °F	Orientation Release Stress, psi
1	325	262
2	325	263
3	330	275
4	332	239
5	335	242
Average	331	254

3.2 Tested Normal To Direction of Isotrophy

1	312	321
2	329	284
3	320	270
4	325	276
5	322	299
Average	322	290

APPROVED ENGINEERING TEST LABORATORIES

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Francis Pickell Sr., P.E.
Project Engineer

REGISTERED PROFESSIONAL ENGINEER FRANCIS PICKELL, SR. QU 1224 QUALITY STATE OF CALIFORNIA

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A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12122 Western Ave.
Garden Grove, California 92642

Report No. 877-3066-3
P.O. No. 31466
Date: 18 September 1978

1.0 TEST ITEM

One Plastic Film Material marked El Rexene #PP-41-6300-4153

2.0 TEST PERFORMED

Orientation release stress per ASTM D150420, except air medium was used.

3.0 TEST RESULTS

3.1 Tested Parallel to Direction of Isotrophy

Specimen No.	Maximum Temperature Attained, °F	Orientation Release Stress, psi
1	293	606
2	295	681
3	290	633
4	285	556
5	290	597
Average	291	615

3.2 Tested Normal To Direction of Isotrophy

Specimen No.	Maximum Temperature Attained, °F	Orientation Release Stress, psi
1	305	1.8
2	300	.9
3	300	.8
4	295	1.1
5	305	1.3
Average	301	1.2

REGISTERED PROFESSIONAL ENGINEER FRANCIS PICKELL, SR. QU 1224 QUALITY STATE OF CALIFORNIA

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Francis Pickell Sr., P.E.
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A NATIONAL TECHNICAL SERVICES COMPANY

TESTED FOR

Swedlow, Inc.
12122 Western Ave.
Garden Grove, California 92645

Report No. 977-3505
P.O. No. 34943
Date: 26 March 1979

1.0 TEST ITEM

One Plastic Film Material marked Hercules EK-500

2.0 TEST PERFORMED

Orientation release stress per ASTM D1504-70, except air medium was used.

3.0 TEST RESULTS

Tested Parallel to directiron of Isotrophy

Specimen No.	Maximum Temperature attained, °F	Orientation Release Stress, psi
1	323	224
2	320	219
3	320	212
4	322	205
5	324	209
Average	322	214

3.2 Tested Normal to Direction of Isotrophy

Specimen No.	Maximum Temperature attained, °F	Orientation Release Stress, psi
1	318	162
2	322	164
3	320	152
4	318	153
5	320	150
Average	320	156

APPROVED ENGINEERING TEST LABORATORIES

Francis Pickell Sr.

Francis Pickell Sr.,P.E.
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APPENDIX E

SPECIFICATIONS

Engineering Report No. 948 - Test Procedure for Determining the Optimum Processing Condition for Transparent Polyolefin Film Armor

Engineering Report No. 990 - Material Procurement Specification - Polypropylene Film for Transparent Armor

Engineering Report No. 991 - Process Specification - Production of Transparent Polyolefin Film Armor

Swedlow Inc. Garden Grove, Calif.

DATE OF ISSUE 2/28/79	Swedlow Inc.	NUMBER 948
PREPARED BY R. Shelton		TYPE
REVISION A — REVISED BY C. Gibson 4/13/79	ENGINEERING REPORT	CLASSIFICATION Non-Proprietary
B		STAMP IF PROPRIETARY
C		
D		

TITLE: TEST PROCEDURE FOR DETERMINING THE OPTIMUM PROCESSING CONDITION FOR TRANSPARENT POLYOLEFIN FILM ARMOR

REVISION INFORMATION (DATES, ETC.) LIST AMENDMENTS HERE

REVISION "A" - Dated April 12, 1979

SWEDLOW APPROVALS

REVISION	CHECKED BY	APPROVAL	APPROVAL	APPROVAL
	C. Gibson 3/1/79	C. Lingle		
A	C. Gibson 4/13/79	R. Shelton 4-13-79		
B				
C				
D				

CUSTOMER APPROVALS (IF REQUIRED)

REVISION	CHECKED BY	APPROVAL	APPROVAL	APPROVAL
A				
B				
C				
D				

TABLE OF CONTENTS

1.0 SCOPE

This procedure establishes the method to be used by Swedlow in determining the optimum processing conditions, with a minimum number of experiments, for Transparent Polyolefin Film Armor.

The procedure to be used will be a two factorial experimental plan where three factors (temperature, pressure and time) are evaluated at three different levels.

2.0 REFERENCES

1. Contract Number DAAG-46-76-C-0034, Amendment Number P00001.

2. Box, G.E.P. and Behnken D.W. "Some New Three Level Designs for the Study of Quantitative Variables", Technometrics 2, pp 455-475 (1960).

3. The Design and Analysis of Industrial Experiments, Second Edition, Edited by O. L. Davies.

3.0 BACKGROUND

Prior to any experimental work, parameters were established by AMMRC as guidlines for Task III, (Ref. 1., paragraph F-2.2.3.2). These preliminary guidelines are shown in Table 1.

TABLE 1

PRELIMINARY GUIDELINES
FOR TASK III

ITEM	UNITS	LOW	HIGH
a) Temperature	^{o}F	300	380
b) Pressure	PSI	100	8000
c) Time	Minutes	20	60

We believe that these molding guidelines should be modified to a more meaninful span. Tests to date indicate that molding at $300^{o}F$ does not allow lamination to take place, while $380^{o}F$ is in the melt region allowing excessive flow and loss of clarity.

Results of the moldings of EK 500 film for Task II indicates that increasing temperature generally decreases the light transmission and increases the haze. This can be seen in Figure 1. It can also be noted that the maximum light transmission and minimum haze are obtained when the maximum molding temperature is slightly below the crystalline melting point of the EK 500 film, which is 333°F.

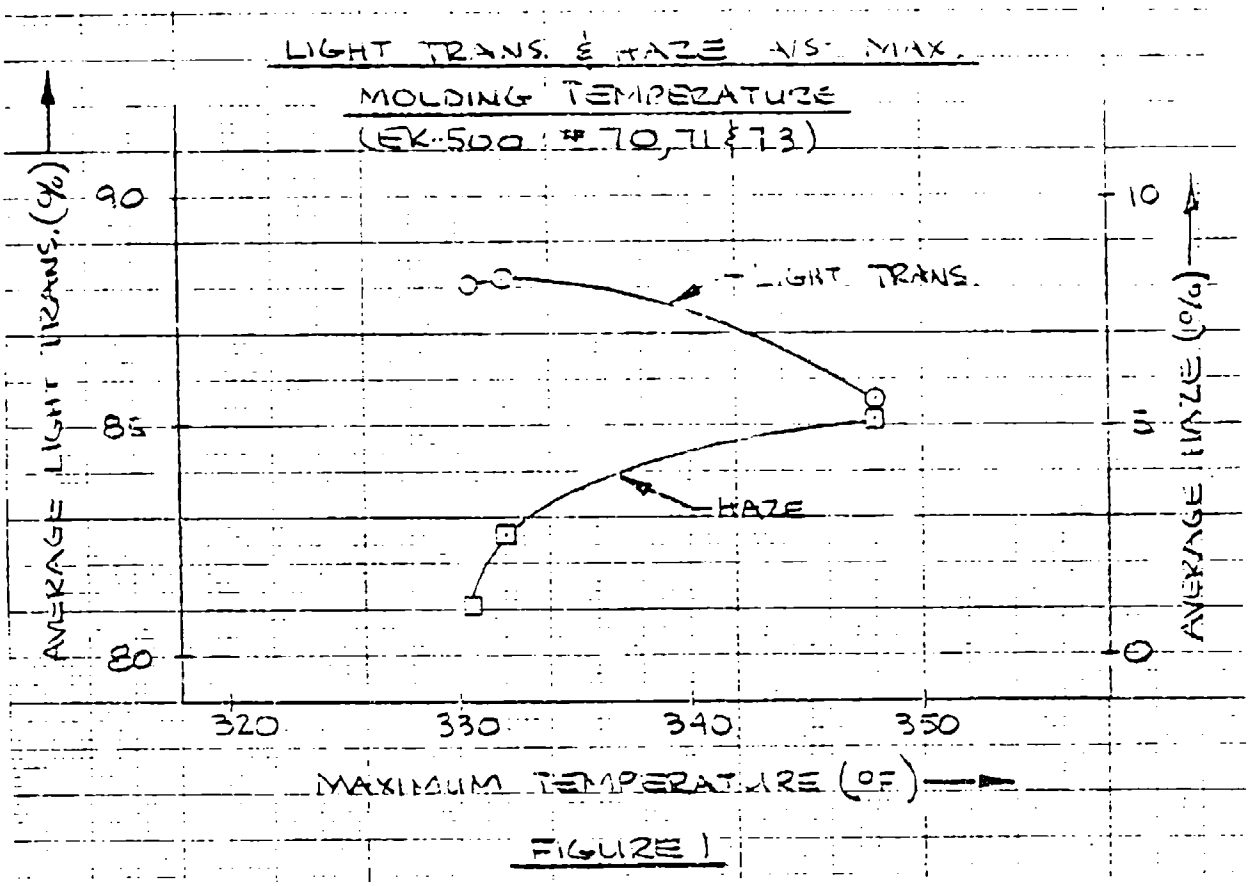


FIGURE 1

The range of pressure desired seems to be excessive, especially since a two level factorial program loses accuracy rapidly as the range of parametric variation increases.

It also seems that the time element could be reduced. Adequate adhesion, commensurate with ballistics resistance, has been obtained with somewhat less time at temperature.

4.0 PROCEDURE

Based on the data obtained to date with molding EK500 film, and a discussion with the C.O.R., we have established a new set of guidlines, resulting in the Box-Behnken Design, (Paragraph 11.2, of Ref. 2), shown in Table 2. (Table 2 reflects the new range of independent variables as agreed upon.

TABLE 2

INDEPENDENT VARIABLES

	ITEM	UNITS	LOW	MIDDLE	HIGH
a)	Temperature	^{o}F	300	330	360
b)	Pressure	PSI	100	1550	3000
c)	Time	Minutes	1	30	60

DEPENDENT VARIABLES

	ITEM	UNITS	TEST METHOD
d)	Light Transmission	%	ASTM-D-1003
e)	Haze	%	ASTM-D-1003
f)	Ballistics	V_{50}	MIL-STD-662
g)	Interlaminar Shear	PSI	MIL-P-25690, Para. 4.6.9
h)	Resistance to Debonding	-	ASTM-D-756, Proc. E. ($-57^{o}C$)
i)	Deviation	Minutes of Arc	ASTM-D-881-48
j)	Thickness	Inches	ASTM-D-374

As a result, the "Experimental Schedule", shown in Table 3, is proposed. (This experimental schedule follows that shown in Table 11.1a of Ref. 2).

TABLE 3

EXPERIMENTAL SCHEDULE

RUN NUMBER	TEMPERATURE (°F)	PRESSURE (PSI)	TIME (MINUTES)
1	330	1550	30
2	360	100	30
3	360	1550	60
4	300	3000	1
5	300	3000	30
6	300	1550	1
7	360	3000	30
8	330	1550	30
9	300	100	30
10	300	1550	60
11	330	3000	60
12	330	100	60
13	360	1550	1
14	330	100	1
15	330	1550	30

The run data will be recorded on run sheets shown in Figure 2.

At the completion of one test sequence, (runs 1 thru 15 of Table 3), the samples will be measured for the dependent variables d) and e) of Table 2. The molded samples will then be delivered to AMMRC for ballistics evaluation. These results (including ballistics), will then be analyzed, informally, and if necessary, adjustment of some factor levels will be made or individual points will be moved slightly.

Based on the results obtained, a second test sequence may be made. If a second test sequence is necessary, the samples will be evaluated as described above.

The results obtained from the one or two test sequences will provide a basis for selecting an optimum molding cycle. The data will be recorded as shown in Table 4.

TABLE 4

RUN NUMBER	a TEMP	b PRESS	c TIME	d LIGHT TRANS	e HAZE	f BALLISTICS
1	0	0	0			
2	+	-	0			
3	+	0	+			
4	-	+	-			
5	-	+	0			
6	-	0	-			
7	+	+	0			
8	0	0	0			
9	-	-	0			
10	-	0	+			
11	0	+	+			
12	0	-	+			
13	+	0	-			
14	0	-	-			
15	0	0	0			

The optimum molding cycle will be selected as follows. (Paragraph 11.5 of Ref. 2).

- o A three-dimensional cube will be drawn, in perspective, and the observed d), e), and f) values will be entered at the appropriate points. The points where the observed response is highest and lowest will be noted.

- o The point or points at which the best combination of responses is found will be identified. The corresponding a), b), and c) combinations should be good estimates of the best operating conditions of the process.

The selected cycle, (optimum), will be utilized to produce approximately six moldings. Three will be tested by Swedlow to the requirements of Table 2, dependent variables d), e), g), h), i), and j); and three will be delivered to AMMRC for ballistics testing (Table 2, f).

PRESS LAMINATION REPORT - EK500 FILM

TRANSPARENT POLYOLEFIN FILM ARMOR

CONTRACT NUMBER DAAG-46-76-C-0034

UNIT NO._____ UNIT SIZE_____ PRESS DATE_____

CROSS PLY DATA-PLIES_____ BY_____

OR UNIT WEIGHT _____ GMS.

DRYING CYCLE-VACUUM_____ TIME_____ TEMP_____

PRESS CYCLE-PLATEN TEMP_____ PRESS NO._____

PRESSURE_____ PSI

MOLDING DATA-EXPERIMENTAL RUN NO. _____

TIME	PSI	TEMP	TIME	PSI	TEMP

Remarks

LAMINATE-WEIGHT_____ GMS._____ LBS/FT^2

FIGURE 2

12122 WESTERN AVENUE/GARDEN GROVE, CALIFORNIA 92645/714-893-7531 TELEX 678467

SWEDLOW, INC.

ENGINEERING REPORT NO. 990

MATERIAL PROCUREMENT SPECIFICATION

POLYPROPYLENE FILM FOR TRANSPARENT ARMOR

Prepared For

Army Materials and Mechanics
Research Center (AMMRC)
Watertown, Mass. 02172

Contract Number DAAG-46-76-C-0034,
Amendment Number P00002

FOREWORD

This Material Procurement Specification was prepared by Swedlow, Inc. under Army Materials and Research Center, (AMMRC), Contract Number DAAG-46-76-C-0034, Amendment P00002.

TABLE OF CONTENTS

1.0 SCOPE

1.1 This specification is for use in the procurement of clear, colorless, heat-set biaxially oriented polypropylene homopolymer film. It specifies the requirements the material must meet to be acceptable for the production of transparent film armor and provides the receiving inspection procedure and test methods to be employed in assuring conformance to the requirements of this specification.

2.0 REFERENCES

2.1 ASTM Standards - Methods of Testing.

3.0 REQUIREMENTS AND TEST METHODS

3.1 The biaxially oriented polypropylene film, as received, shall conform to the requirements of Table 1.

3.2 Conformance to the requirements of Table 1 will be determined by the test methods shown in the same table.

4.0 RECEIVING INSPECTION

NOTE: Do not handle polypropylene film with bare hands. Use clean, disposable, polyethylene gloves at all times.

4.1 Two samples of the film material will be taken from one roll and one sample will be delivered to the test laboratory for evaluation.

4.2 Evaluation will consist of the tests and methods shown as Items 1 through 9 in Table 1.

4.3 If the first film sample meets the requirements of Items 1 through 9 of Table 1, the second sample will be sent to an outside qualified test laboratory for determination of the Orientation Release Stress, Item 10 of Table 1.

5.0 ACCEPTANCE

5.1 After arrival, the film shall be impounded until released by the Receiving Inspection Department.

5.2 Upon release of the Acceptance Report from the test laboratory, the Receiving Inspection Department shall approve release of the film for production.

6.0 RETEST

6.1 If the film sample fails to meet all the requirements of Table 1, a second sampling may be taken.

6.2 If the second film sampling passes all the requirements of Table 1, the film shall be approved as noted in Section 5.0.

7.0 REJECTION

7.1 Failure of the second film sample to meet all the requirements of Table 1 shall be cause for rejection.

TABLE 1

ORIENTED POLYPROPYLENE FILM

REQUIREMENTS AND TEST METHODS

Item	Property	Test Method	Requirement
1	Thickness, Inches	ASTM D-374	0.001 (1)
2	Melting Point, °C (°F)	ASTM D-2217	167 (332.6) (1)
3	Specific Gravity	ASTM D-792	0.902 (1)
4	Water Absorption, %	ASTM D-570	< 0.005
5	Light Transmission, %	ASTM D-1003	>91.0
6	Haze, %	ASTM D-1003	< 2.0
7	Tensile Strength, PSI	ASTM D-882, Method A	30,000 Machine (1) and Transverse
8	Tensile Modulus, PSI	ASTM D-882, Method A	350,000 Machine (1) and Transverse
9	Elongation, %	ASTM D-882, Method A	70-100
10	Orientation Release Stress	ASTM D-1504	
	Temperature, °F		300 Minimum
	Release Stress, PSI		200 Minimum machine, 150 Minimum transverse

(1) Manufacturers' tolerance apply.

APPROVED MATERIALS

Product	Manufacturers Designation	Source
Clear, Colorless, Heat-set, Biaxially Oriented Polypropylene Homopolymer Film	EK-500	Hercules Inc. Film Division Wilmington, Delaware 19899

2122 WESTERN AVENUE/GARDEN GROVE, CAUFORNIA 92645/714-893-7531 TELEX 67845?

SWEDLOW, INC.

ENGINEERING REPORT NO. 991

PROCESS SPECIFICATION

PRODUCTION OF TRANSPARENT POLYOLEFIN FILM ARMOR

Prepared For

Army Materials and Mechanics
Research Center (AMMRC)
Watertown, Mass. 02172

Contract Number DAAG-46-76-C-0034,
Amendment Number P00002

FOREWORD

This Process Specification was prepared by Swedlow, Inc. under Army Materials and Mechanics Research Center, (AMMRC), Contract Number DAAG-46-76-C-0034, Amendment P00002.

TABLE OF CONTENTS

TABLES AND FIGURES

1.0 SCOPE

1.1 This process specification describes the materials and procedures required for converting polyolefin film into bonded sheet having good ballistic, optical and resistance to debonding characteristics.

2.0 REFERENCES

2.1 Drawings

2.1.1 AMMRC

CD-1 Transparent Polypropylene Film Windows

2.1.2 Swedlow

77050 Assembly-Chase Mold (12" x 12") - AMMRC
Transparent Armor Test Plaques

80025 Assembly-Chase Mold - AMMRC
Transparent Armor Windows

2.2 Other

ASTM Standards - Methods of Testing
Federal Standard 209 - Clean Room and Work Station Requirements, Controlled Environment.

3.0 REQUIREMENTS - FILM

3.1 A clear, colorless, heat-set, biaxially oriented polypropylene homopolymer film meeting the requirements of Material Procurement Specification ER-990.

4.0 REQUIREMENTS - MOLDED SHEET

4.1 After converting, the molded sheet shall conform to the Requirements of Table 1.

4.2 Conformance to the requirements of Table 1 will be determined by the test Methods shown in the same table.

4.3 The molded sheet shall be free of delamination.

4.4 Optical defects such as inclusions, wrinkles, roll flaws, die lines or orange peel shall not be grouped in such a manner as to cause vision impairment.

4.5 The maximum deviation, line of sight, shall not exceed the limit shown in Table 1 except for an area within two inches of the trimmed edge, where such requirements shall be disregarded.

5.0 MATERIALS

5.1 The following material shall become the finished product.

5.1.1 Clear, biaxially oriented polypropylene film as described in paragraph 3.1.

5.1.2 A transparent abrasion resistant protective coating.

Source: See paragraph 7.5.6

5.2 The following materials are not incorporated into the finished product, but are required for part preparation.

5.2.1 Bleached cheesecloth -

Source: Industrial Textiles
Los Angeles, Ca.

5.2.2 Capron 80, 0.002 inch thick, 80 inch wide roll.

Source: Allied Chemicals
Los Angeles, Ca.

5.2.3 Vacuum Bag Sealer. Vac-Seal Type 1191 (Zinc Chromate, green, 1/8 inch by 1/2 inch by length).

Source: Hastings Plastics
Santa Monica, Ca.

5.2.4 Isopropyl Alcohol, reagent grade.

Source: Van Waters and Rogers
Norwalk, Ca.

5.2.5 Masking Tape. 3M 209, Permacel P-70, or equal.

5.2.6 Gloves, polyethylene, disposable.

5.2.7 Masking Paper: St. Regis WPL-3

Source: St. Regis, Sherman Division
Los Angeles, Ca.

5.2.8 Vacuum Bleeder Material. NN 121 synthetic cloth.

Source: J. P. Stevens, Inc.
Garfield, New Jersey

6.0 EQUIPMENT

6.1 Vacuum Pump

6.1.1 A heavy duty vacuum pump, capable of maintaining a minimum of 24 inches of mercury vacuum, shall be required as part of the drying equipment.

6.2 Laminating Mold.

6.2.1 The laminating mold shall be of aluminum construction in accordance with the design in drawings 77050 and 80025.

6.3 Polish Plates.

6.3.1 Chrome on Brass, mirror finish one side.

Source: Weiland America Inc.
Orange, New Jersey

6.4 Anti-Static Bar.

6.4.1 3M Number 210 or equal.

6.5 Anti-Static Air Nozzle.

6.5.1 3M Number 902 or equal.

7.0 MANUFACTURING PROCESS

NOTE: 1. Do not handle polyolefin film or molded sheet with bare hands. Use clean, disposable, polyethylene gloves at all times.

2. Film layup, mold and press polish plate cleaning, and assembly for molding shall be accomplished in a clean room, class 100,000 or better, in accordance with Federal Standard 209.

7.1 Film Layup.

7.1.1 Withdraw a roll of EK-500 film from stores and have slit to the required size. (A minimum of two inches greater than the final molded size has been found acceptable.)

7.1.2 One method of roll set-up for film takeoff is illustrated in Figure 1.

7.1.3 Wind a convenient number of plies of EK-500 film on a winding mandrel. (Fifty plies has been found to be a convenient number). Lay the EK-500 film on a clean piece of EK-500. Continue the winding and layup until the required number of plies are attained as shown below. Between successive layups blow off the film using an anti-static air nozzle.

Nominal Thickness (Inches)	Weight Ounces/Square Foot	Approximate Number of Plies of EK-500
0.264	20.0	264
0.094	7.12	94
0.313	23.71	313

When laying up the film, add ten plies of film to each side. These extra plies of film are to aid in preventing contamination and are removed prior to molding.

7.1.4 When the required number of plies has been attained, cover wrap the unit with clean, dry EK-500 film.

7.2 Deaeration.

7.2.1 Place wrapped unit on a flat plate. Place bleeder material around the edge of the unit.

7.2.2 Adhere vacuum bag sealer tape number 1191 to the plate approximately two inches outside and around the bleeder material.

7.2.3 Cut a piece of capron film at least six inches oversize, and lay up on top of the unit.

7.2.4 Remove the waxed release paper from the vacuum sealer tape and adhere the capron film to fit loosely over the unit. Make pigtails where there is excess capron.

7.2.5 Apply vacuum, 20-24 inches of Mercury, for a minimum of eight hours.

7.3 Trimming.

7.3.1 After deaeration, use a power shear and trim the wrapped, compressed unit to the required molding size. (The molding size is 0.031 inches less than the inside dimension of the mold.)

Leave the protective EK-500 film on the unit during trimming. Take all precautions to prevent contamination.

7.3.2 After trimming, immediately rewrap unit with clean, dry EK-500 film.

7.4 Drying.

7.4.1 Repeat paragraphs 7.2.1 through 7.2.4.

7.4.2 Apply vacuum, 20-24 inches of Mercury, for a minimum of twelve hours.

7.4.3 Care must be taken to keep stack edges square.

7.5 Preparation for Molding.

7.5.1 Polish plates.

7.5.1.2 Thoroughly clean the press polish plates. Blow off all foreign material with an anti-static air nozzle. Clean the press polish plate with clean cheesecloth saturated with Isopropyl Alcohol. Wipe with clean dry cheesecloth and repeat.

7.5.2 Mold.

7.5.2.1 Thoroughly clean the mold using the same procedure as described in paragraph 7.5.1.2.

7.5.3 Assembly

7.5.3.1 Place one press polish plate in the bottom portion of the mold, polish surface up.

7.5.3.2 Remove the unit of EK-500 from under vacuum and transport to the clean room for stripping and/or weighing.

7.5.3.3 Remove the protective EK-500 film and the required number of plies evenly from each side, to achieve the nominal thickness/weight as shown in paragraph 7.1.3.

7.5.3.4 Place the EK-500 unit on the press polish plate.

7.5.3.5 Position a thermocouple wire in the unit, mid-stack, no more than one-fourth inch in from the edge. Secure to the mold with masking tape.

7.5.3.6 Place the second press polish plate on top of the unit, polish surface down.

7.5.3.7 Place the top portion of the mold on the top press polish plate. (A sectional view of the molding assembly is shown in Figure 2).

7.5.4 Molding

NOTE: All molding data to be recorded every five minutes on a run sheet as shown in Figure 3.

7.5.4.1 Load the assembly into a cold press. (Platen temperature $\leq$ 100°F).

7.5.4.2 Attach the thermocouple wire to the potentiometer.

7.5.4.3 Close the press and set the pressure to 2000 PSI.

7.5.4.4 Turn on the steam to the press platens until the mid-stack temperature reaches + 330°F. Maintain a mid-stack temperature of + 330°F, + 5°F -0°F for thirty minutes.

7.5.4.5 Turn the steam pressure off and hold for ten minutes.

7.5.4.6 Force cool the assembly by passing water through the press platens until the mid-stack temperature is $\leq$ 100°F.

7.5.4.7 Release pressure and remove mold from the press.

7.5.4.8 Remove molded EK-500 unit from mold and identify with a serial number.

7.5.5 Quality Control.

7.5.5.1 Quality Control shall visually inspect the molded unit for voids, unbonded areas, general optical quality, luminous transmittance, haze and thickness.

7.5.6 Protective Coating.

7.5.6.1 Units acceptable from paragraph 7.5.5.1 shall have both surfaces coated with an abrasion resistant protective coating.

7.5.6.2 The materials and process used for applying the protective coating was developed prior to this contract and, as such, is not a part of this process specification. Protective coating capability, including the process and facilities, is currently available from several transparency fabricators.

7.5.7 Quality Control.

7.5.7.1 Quality control shall inspect the molded units with protective covers as specified in paragraph 7.5.5.1.

7.5.7.2 Acceptable units shall be machined to the triangular shape as shown in AMMRC Drawing CD-1, as follows.

7.5.8 Machining.

7.5.8.1 The molded unit is protected on each surface with WPL-3 protective paper.

7.5.8.2 The molded unit is band sawed one-inch oversize, to the approximate shape of the window.

7.5.8.3 The window is machined to final dimensions as follows.

7.5.8.3.1 To prevent delamination, a 0.125 inch thick sheet of acrylic is placed on each side of the molded panel. Sufficient pressure is applied to prevent slipping. Routing is then accomplished with an 18000 RPM hand held router using a 0.500 inch diameter, two flute carbide inlaid router bit.

7.5.8.3.2 The machined panel is then submitted to Quality Control.

7.5.9 Quality Control

7.5.9.1 Quality Control shall determine compliance with the drawing dimensions.

7.5.9.2 Quality Control shall determine compliance with Items 1,2,3,4 and 8 of Table 1.

7.5.9.3 Every tenth unit shall be tested to determine compliance with Items 5 and 6 of Table 1.

7.5.9.4 Compliance to Item 7 of Table 1 is to be determined by the Army Materials and Mechanics Research Center (AMMRC).

8.0 PACKAGING/DELIVERY

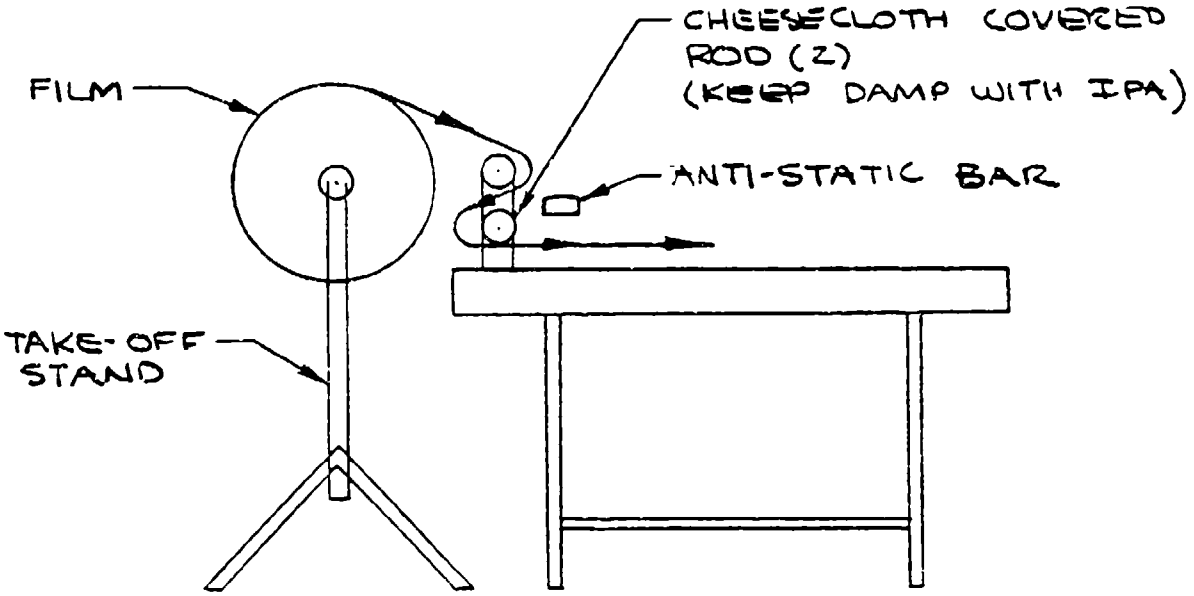
The completed unit shall be protected by sealing in a 0.002 inch polyethylene film envelope and delivered to the customer.

TABLE 1

MOLDED POLYOLEFIN FILM ARMOR

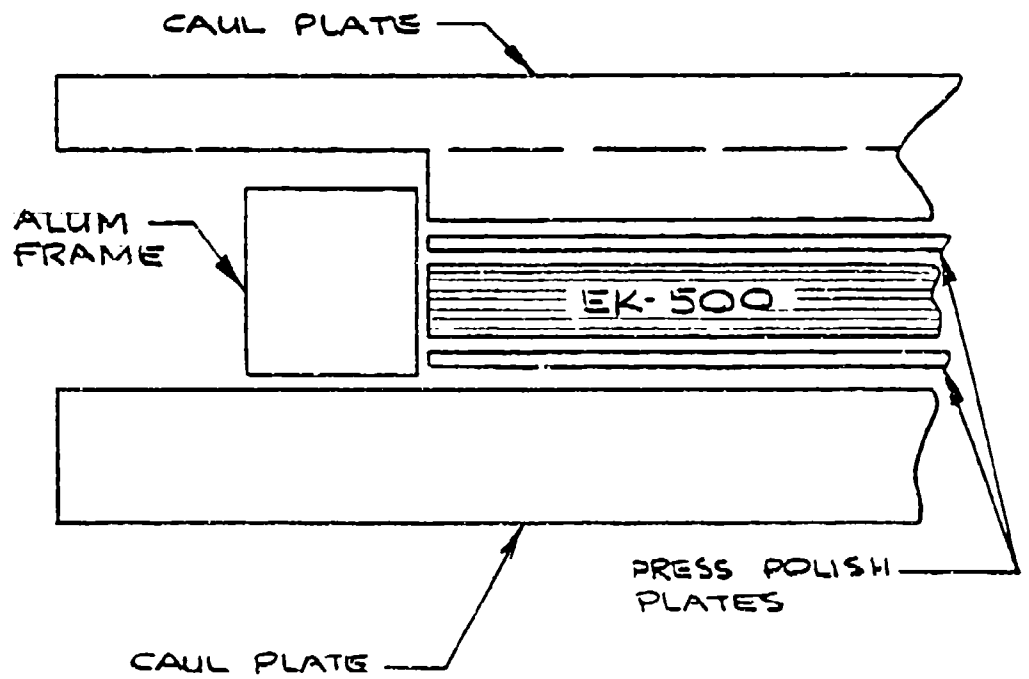
REQUIREMENTS AND TEST METHODS

Item	Property	Test Method	Requirement
1	Weight, Ounces/Foot^2	---	Paragraph 7.1.3
2	Light Transmission, %	ASTM D-1003	> 82.0
3	Haze, %	ASTM D-1003	< 4.0
4	Maximum Deviation, Line of Sight-Minutes of Arc	ASTM D-881-48	< 7.0
5	Resistance to Debonding	ASTM D-756 (Procedure E, -57°C Low Temperature)	Minimum of 5 Cycles without Debonding
6	Interlaminar Shear Strength, PSI	MIL-P-25690, Paragraph 4.6.9	> 1000
7	Ballistics, V_{50}	MIL-STD-662	Maximum
8	Thickness	ASTM D-374	± 5%



ROLL SETUP FOR FILM TAKEOFF

FIGURE 1



MOLDING ASSEMBLY

FIGURE 2

PRESS LAMINATION REPORT - EK500 FILM

TRANSPARENT POLYOLEFIN FILM ARMOR

CONTRACT NUMBER DAAG-46-76-C-0034

UNIT NO._____ UNIT SIZE_____ PRESS DATE_____

LAY-UP DATA-PLIES _____ BY_____

OR UNIT WEIGHT _____GMS.

DRYING CYCLE-VACUUM_____ TIME_____ TEMP_____

PRESS CYCLE-PLATEN TEMP_____ PRESS NO._____

PRESSURE_____PSI

MOLDING DATA-EXPERIMENTAL RUN NO. _____

TIME	PSI	TEMP	TIME	PSI	TEMP

Remarks

LAMINATE-WEIGHT_____GMS._____LBS/FT^2

FIGURE 3

APPENDIX F

DRAWINGS

AMMRC

CD-1 Transparent Polypropylene Film Windows

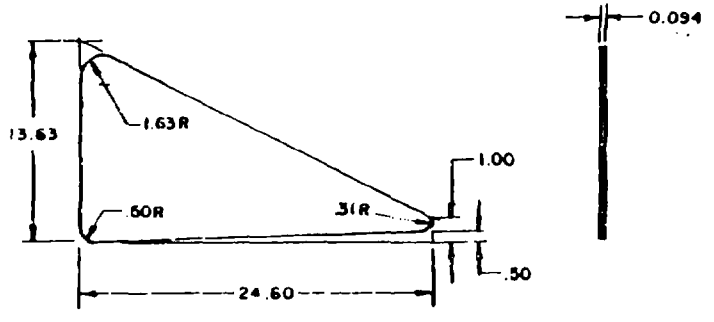
SWEDLOW, Inc.

77050 Assembly - Chase Mold (12" x 12") - AMMRC. Transparent Armor Test Plaques

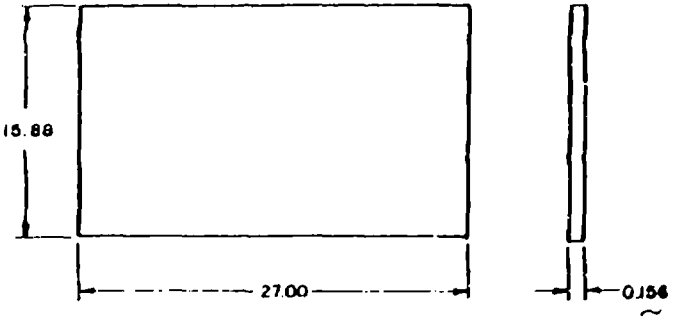
80025 Assembly - Chase Mold - AMMRC Transparent Armor Windows

B

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL



TRIANGULAR WINDOW



RECTANGULAR WINDOW

PHYSICAL PROPERTIES			
TP			
TS			
EL %			
FA			
BH			
BM			

NEXT ASSY		USED ON
APPLICATION		
DO NOT		APPLY PART NO
DO		AS SPECIFIED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ±.010
ANGLES ±1° FRACTIONS
MATERIAL
HEAT TREATMENT
FINAL PROTECTIVE FINISH

ORIGINAL DATE OF DRAWING 22 MAR 1976

DRAFTSMAN STW	CHECKER
TRACER	CHECKER
ENGINEER	ENGINEER

SUBMITTED

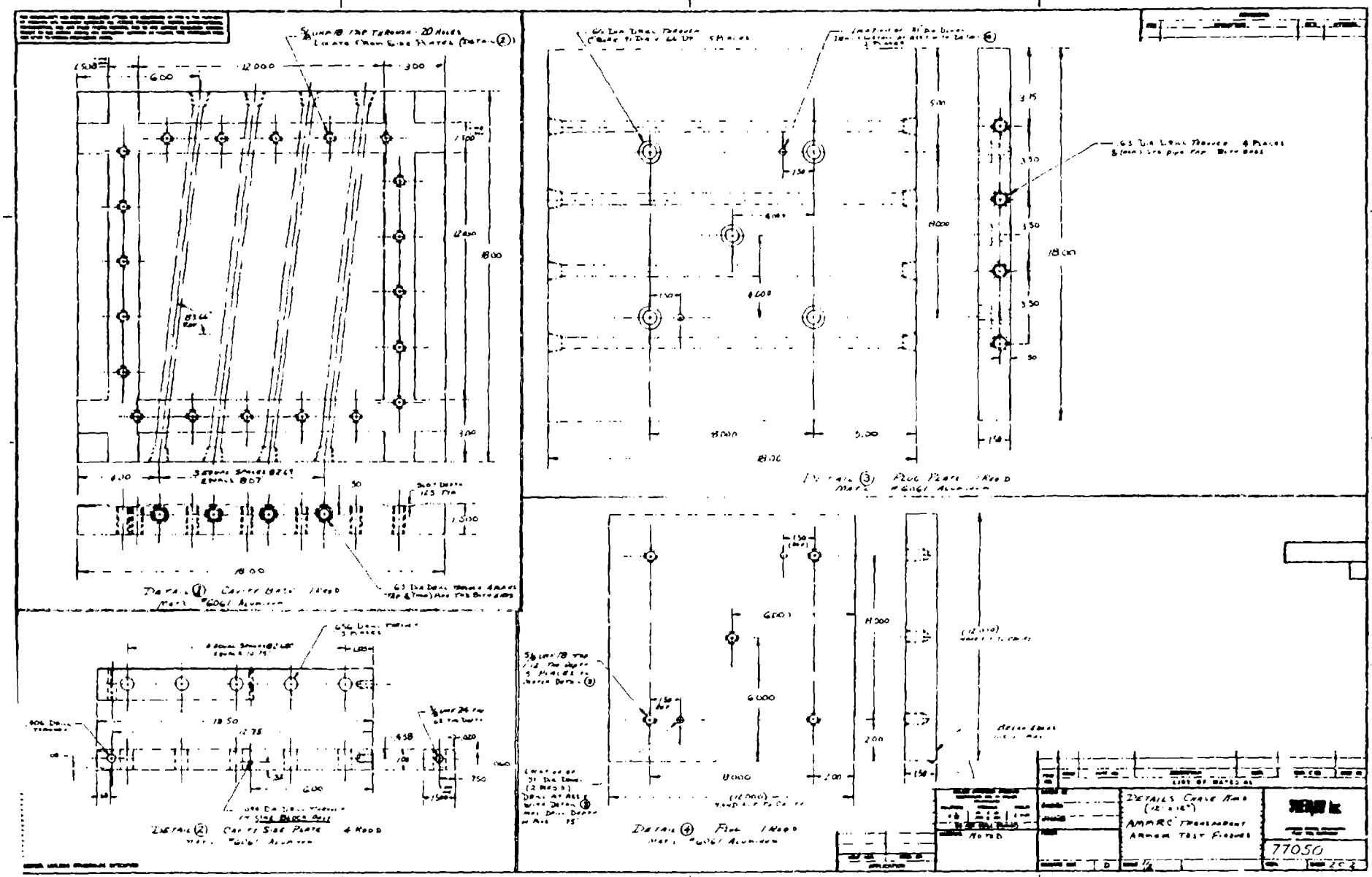
APPROVED BY ORDER OF THE ~~SHIRE OF ORDNANCE~~

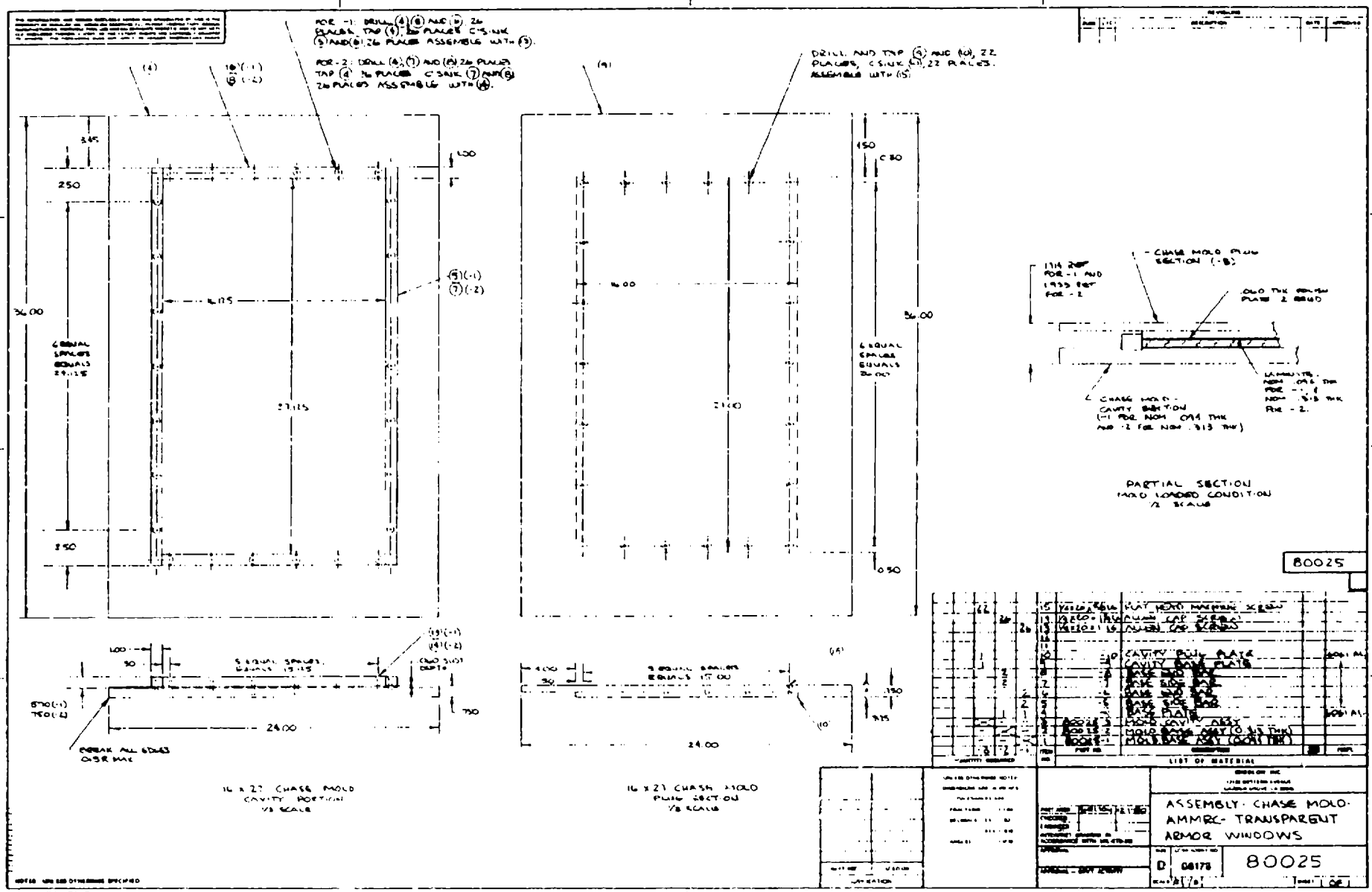
TRANSPARENT POLYPROPYLENE FILM WINDOWS

SCALE 1/8" = 1'-0" UNIT WT

AMMRC
COMPOSITES DIVISION

DWG SIZE	CD-1
B	SHEET 1 OF 1


DETAILS CRANE ARMS
(12' & 16')
AMARC TREATMENT
ARMOR TEST PIECES
770.50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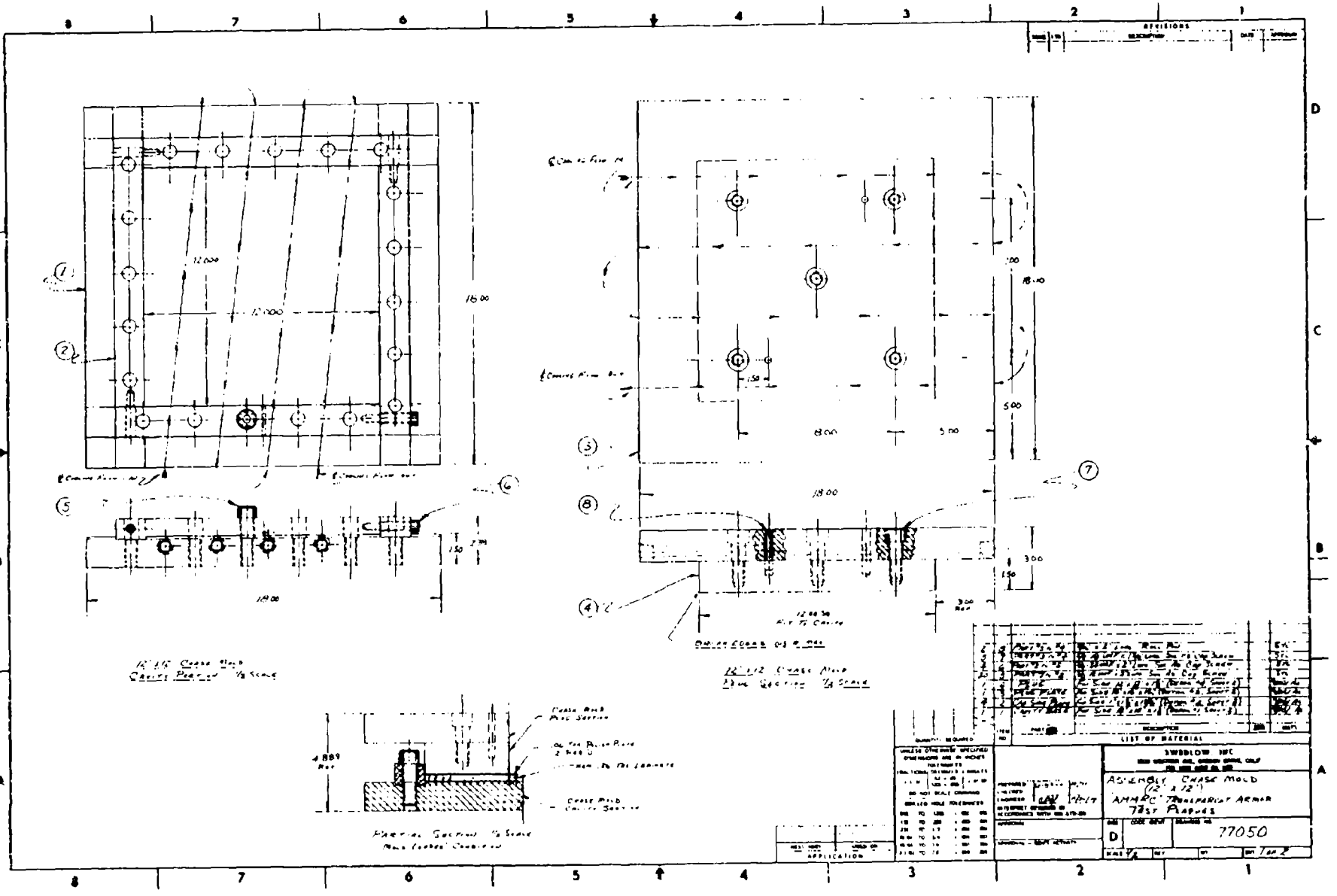
FOR -2: DRILL (4) (7) AND (8) 26 PLACES TAP (4) 26 PLACES C'SINK (7) AND (8) 26 PLACES ASSEMBLE WITH (4).
DRILL AND TAP (5) AND (10) 22 PLACES, C'SINK (5) 22 PLACES. ASSEMBLE WITH (5).
36.00
23.115
24.00
21.00
6.00
PARTIAL SECTION
MOLD LOADED CONDITION
1/2 SCALE
16 x 22 CHASE MOLD
CAVITY PORTION
1/8 SCALE
16 x 21 CHASE MOLD
PLUG SECTION
1/8 SCALE
80025
LIST OF MATERIAL
ASSEMBLY - CHASE MOLD - AMMRC - TRANSPARENT ARMOR WINDOWS
D
80025


REVISIONS
LIST OF MATERIAL
SWEDLOW INC.
Assembly Chase Mold
(2 x 12')
AMARC Dragerfist Armor
73sf Panels
77050
D

Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172
TRANSPARENT POLYOLEFIN
FILM ARMOR
Ralph C. Shelton
Swedlow, Inc.
12122 Western Avenue
Garden Grove, CA 92645
Technical Report AMMRC 81-41, August 1981
50 pp, illus., tables, Contract
DAAG46-76-C-0034
D/A Project 1748035 & 1758035
Final Report, March 30, 1976 to February 28, 1981

AD____________
Unclassified
Unlimited Distribution

Key Words

Armor
Transparent
Polyolefin
Film

The general objective of this project was to determine the optimum processing conditions for the large scale conversion, by molding and laminating of oriented polyolefin film into fragment resistant transparent armor suitable for Army aircraft glazing applications. The manufacturing process must produce a laminate with sufficient adhesion to resist debonding during thermal cycling and yet react as a laminar structure during ballistic impact. To accomplish the objectives required the completion of six major tasks. These tasks were successfully performed and the general objective of this project has been achieved. An optimum process has been established, and in the process, areas of further development have been identified.

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Watertown, Massachusetts 02172
TRANSPARENT POLYOLEFIN
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12122 Western Avenue
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Technical Report AMMRC 81-41, August 1981
50 pp, illus., tables, Contract
DAAG46-76-C-0034
D/A Project 1748035 & 1758035
Final Report, March 30, 1976 to February 28, 1981

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Key Words

Armor
Transparent
Polyolefin
Film

The general objective of this project was to determine the optimum processing conditions for the large scale conversion, by molding and laminating of oriented polyolefin film into fragment resistant transparent armor suitable for Army aircraft glazing applications. The manufacturing process must produce a laminate with sufficient adhesion to resist debonding during thermal cycling and yet react as a laminar structure during ballistic impact. To accomplish the objectives required the completion of six major tasks. These tasks were successfully performed and the general objective of this project has been achieved. An optimum process has been established, and in the process, areas of further development have been identified.

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