MLR 75 4

IOWA DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS

OFFICE OF MATERIALS

R - 265

AN INVESTIGATION OF CONCRETE SETTING TIME

MAY, 1975

DEPARTMENT OF TRANSPORTATION
IOWA

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May, 1975

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TABLE OF CONTENTS

		Page No.
1.0	Introduction	1
2.0	Purpose	1
3.0	Scope	2
4.0	Materials	2
5.0	Laboratory Procedure	
	5.1 Testing	3
	5.2 Tabulation of Results	7
6.0	Discussion of Results	19
7.0	Conclusions	27
8.0	Appendix	28

R-265

AN INVESTIGATION OF CONCRETE SETTING TIME

1.0 INTRODUCTION

A water reducing and retarding type admixture in concrete is commonly used on continuous bridge deck pours in Iowa. The concrete placed in the negative moment areas must remain plastic until all the dead load deflection due to the new deck's weight occurs. If the concrete does not remain plastic until the total deflection has occurred, structural cracks will develop in these areas.

Retarding type admixtures will delay the setting time of concrete and prevent structural cracks if added in the proper amounts. In Section 2412.02 of the Standard Specifications, 1972, Iowa State Highway Commission, it states, "The admixture shall be used in amounts recommended by the manufacturer for conditions which prevail on the project and as approved by the engineer." The conditions which prevail on the project depend on temperature, humidity, wind conditions, etc. Each of these factors will affect the setting rate of the plastic concrete.

2.0 PURPOSE

The purpose of this project is to provide data that will be useful to field personnel concerning the retardation of concrete setting times, and how time of sets will vary with different addition rates and curing temperatures holding all other atmospheric variables constant.

3.0 SCOPE

The scope of Project R-265 was limited to investigating four commercial retarders presently in use in Iowa. Three different dosage rates and six different temperatures will be studied.

4.0 MATERIALS

The cement was a blend of Type I (R-11 Blend) from seven different companies that produce for Iowa construction (Lab. No. AC4-407).

The fine aggregate was from Hallett's Ames Pit and complied with Section 4110 of the Standard Specifications of the Iowa State Highway Commission (Lab. No. AAS4-514).

The coarse aggregate for concrete was from Hallett's Ames Pit and complied with Section 4115 of the Standard Specifications of the Iowa State Highway Commission.

The air agent was Ad-Aire produced by Carter Waters of Kansas City, Missouri.

The four different commercial retarders used were:

a. Plastiment as manufactured by Sika Chemical Company.

b. Daratard 17 as manufactured by W.R. Grace & Company.

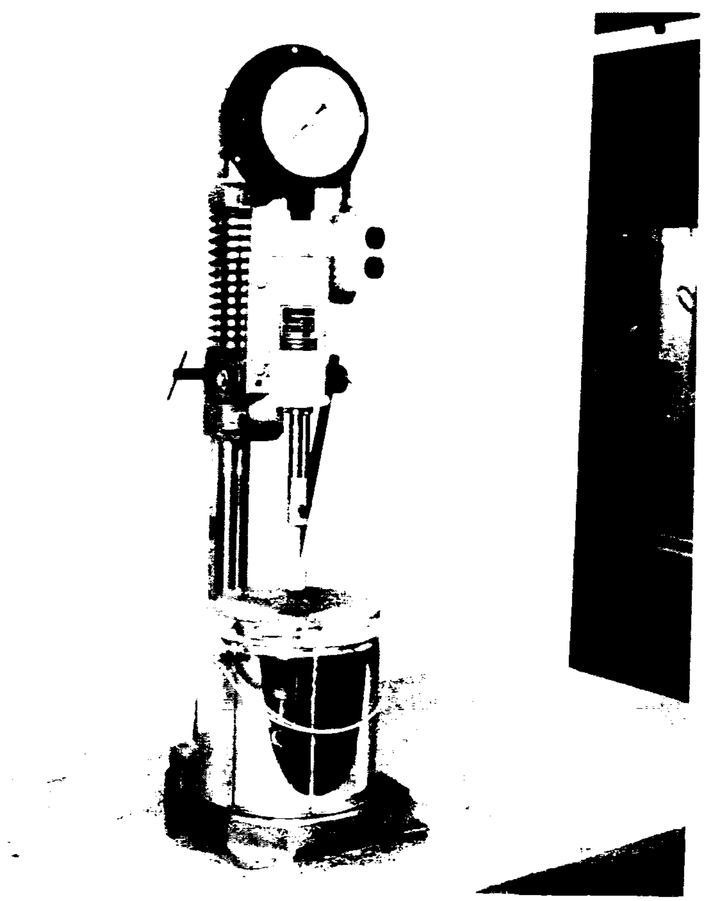
c. Pozzolith 100XR as manufactured by Master Builders Company.

d. Protex PDA-25R as manufactured by Protex Industries Incorporated.

3.0 LABORATORY PROCEDURE

3.1 Testing

The procedure for testing the retarders with different dosage rates and different temperatures was per ASTM C 403-70. The only exception was that only one batch per change in temperature and retarder was tested. The mix proportions for the study were a Class D 57 concrete meeting the requirements of Sec. 2403 of the Standard Specifications of the ISHC. The one exception was that the slump was controlled at 3 $\pm$ ½".



Acme
Penetration Resistance
Apparatus

The time of initial set was determined for the following mixes:

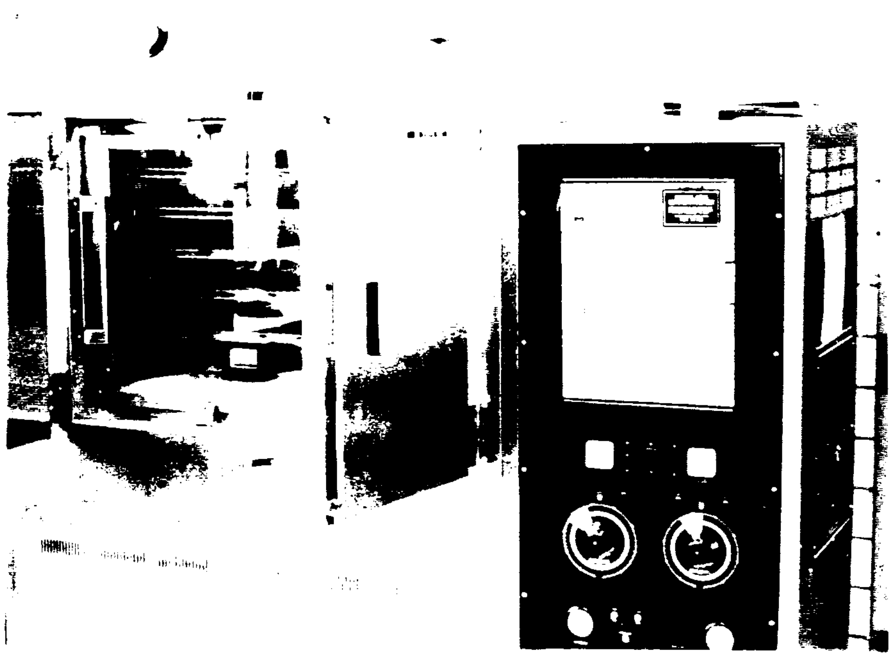
(a) Plastiment admixture at addition rate 3, 4 & 5 fluid ounces per bag of cement at mortar curing conditions of 50% relative humidity and temperatures of 70, 80, 90 and 100° F. Two additional mixes at 3 fl. oz./sk. at temperatures of 50° and 60° F. were also tested.

(b) Daratard 17 admixture at addition rates of 3, 4 & 5 fluid ounces per bag of cement at mortar curing conditions of 50% relative humidity and temperatures of 70, 80, 90 & 100° F.

(c) Pozzolith 100XR admixture at addition rates of 3, 4 & 5 fluid ounces per bag of cement at mortar curing conditions of 50% relative humidity and temperatures of 70, 80, 90 and 100° F.

(d) PDA-25R admixture at addition rates of 4, 5 and 6 ounces per bag of cement at mortar curing conditions of 50% relative humidity and temperatures of 70, 80, 90 and 100° F. Two additional mixes at 4 fl. oz./sk. at temperatures of 50° and 60° F. were also tested.

(e) Control concrete containing no retarder at mortar curing conditions of 50% relative humidity and temperature of 50, 60, 70, 80, 90 and 100° F.



Constant Temperature/Humidity Cabinet
Blue M Engineering Company

CONTROLS

TEMP. (°F)	AVG. TIME of SET (hrs.)	AVG. WATER USED (lbs/ft³)	Ad Aire RATE (fl.oz/sk.)	AVG. SLUMP (ins.)	AVG. AIR CONT. (%)	AVG. TEMP. of MIX (°F)
50	7.93	10.0	1.0 fl. oz./sk.	2-1/2"	6.0	70°
60	5.94	9.9	1.0 fl. oz./sk.	2-3/4"	5.7	66°
70	4.90	9.9	1.0 fl. oz./sk.	2-3/4"	5.8	71°
80	4.08	10.0	1.0 fl. oz./sk.	2-3/4"	6.2	74°
90	3.93	9.9	1.0 fl. oz./sk.	2-1/2"	6.4	65°
100	3.60	10.1	1.0 fl. oz./sk.	2-1/2"	6.3	68°

TABLE 1

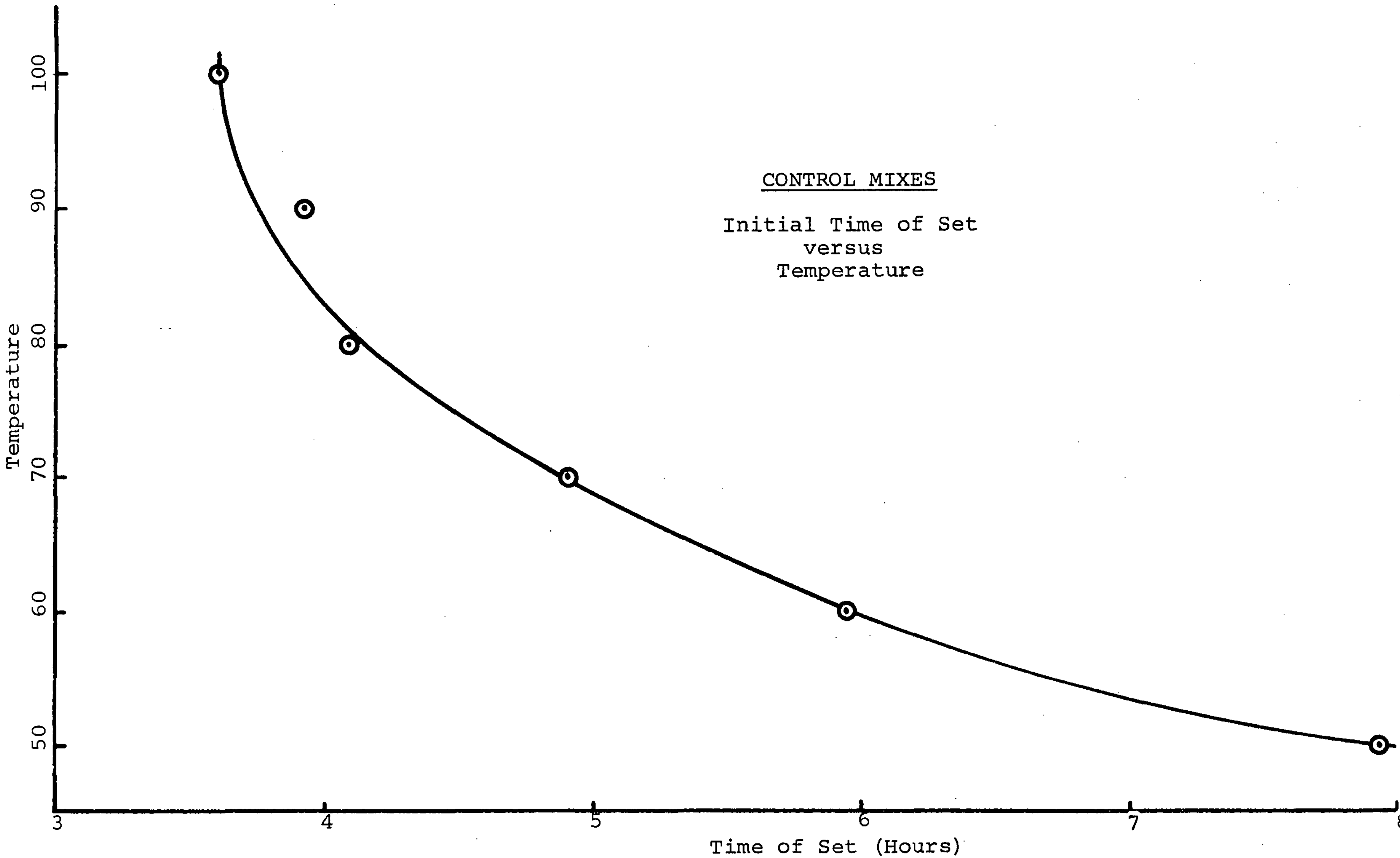

CONTROL MIXES
Initial Time of Set
versus
Temperature
Temperature
100
90
80
70
60
50
3
4
5
6
7
8
Time of Set (Hours)

Figure 1

5.2 TABULATION OF RESULTS

The six control temperatures, 50° thru 100° F. produced the expected time of initial set for each temperature, i.e., as the curing temperature increases, the time of initial set decreases. Table 1 summarizes these control mixes. An Ad-Aire dosage of 1.0 fl. oz./sk. of cement was used for all mixes since it produced air contents in the 5.7 to 6.4% range. The slump and amount of water used with each mix were consistently in the same range. Figure 1 is a summary showing time of initial set versus curing temperature. The individual time of set curves for each curing temperature are included in the Appendix, figures 12 through 17.

The six different curing temperatures for Plastiment are summarized in Tables 2 and 3. Dosage rates for the retarder was 3, 4 and 5 fl. oz./sk. at the 70° to 100° F. temperatures. Only the 3 fl. oz./sk. dosage was used at the 50° and 60° F. curing temperature. See figures 18 through 23 in the Appendix for the individual time of set curves. The normal dosage rate, 3 fl. oz./sk. produced the expected time of set versus temperature curve, Figure 2. However higher dosage rates, 4 and 5 fl. oz./sk. produced erratic points at the higher temperatures.

The Protex PDA 25R retarder was tested at 4, 5, and 6 fl. oz./sk. for temperatures of 70° to 100° F. but only at 4 fl. oz./sk. for the 50° and 60° F. temperatures. See figures 24 through 29 and the Table 4 summarization. Again the normal dosage rate, 4 fl. oz./sk., produced the expected curve, figure 3. However, higher dosage rates, 5 and 6 fl. oz./sk., did not produce predictable results.

Table 5 summarizes the Pozzolith 100XR information. The individual time of initial set curves are shown in figures 30 through 33 in the Appendix. Dosage rates of 3 and 4 fl. oz./100# of cement produced the expected time of sets. See figure 4. The higher dosage rate of 5 fl. oz./100# of cement produced unpredictable results.

All dosage rates for Daratard 17 retarder produced uniform curves; the decrease in curing temperature caused an increase in time of set. See figures 34 through 37. The data from the 90° F. cure should be excluded because the mix temperature was considerably below the other 3 cure temperatures. Table 6 shows a 65° mix temperature at the 90° F. cure and all other cure temperatures are in the 70° F. range. Another reason to ignore the 90° F. cure mixes is because the air contents for these mixes was about 1% above the other 3 mixes.

Table 7 shows the per cent retardation of each retarder at each dosage and curing temperature based on the control mix at the corresponding curing temperature. In general, the per cent retardation increased as the dosage rate of the retarder increased. Also as the curing temperature increased, the per cent retardation decreased.

PLASTIMENT

70°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	7.8 hr	9.6 lbs/ft^3	0.70 fl. oz./sk.	2-1/2"	5.4%	72°
4 fl. oz./sk.	12.97 hr	9.3 lbs/ft^3	0.70 fl. oz./sk.	3-1/4"	6.4%	72°
5 fl. oz./sk.	13.73 hr	9.6 lbs/ft^3	0.70 fl. oz./sk.	3"	6.2%	70°

80°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	7.37 hr	9.4 lbs/ft^3	0.70 fl. oz./sk.	2-3/4"	6.0%	71°
4 fl. oz./sk.	9.32 hr	9.3 lbs/ft^3	0.70 fl. oz./sk.	3-1/2"	6.2%	71°
5 fl. oz./sk.	10.40 hr	9.4 lbs/ft^3	0.70 fl. oz./sk.	3-1/2"	6.0%	71°

90°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	6.75 hr	9.0 lbs/ft^3	0.75 fl. oz/sk.	2-3/4"	6.1%	65°
4 fl. oz./sk.	8.01 hr	9.1 lbs/ft^3	0.75 fl. oz./sk.	3"	6.2%	64°
5 fl. oz./sk.	*13.85 hr 14.65 hr	9.3 lbs/ft^3 9.0 lbs/ft^3	0.75 fl. oz./sk.	3-1/2" 3-1/4"	7.4% 6.4%	67° 67°

* Retest

100°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	5.90 hr	9.1 lbs/ft^3	0.50 fl. oz./sk.	3-1/2"	5.7%	64°
4 fl. oz./sk.	9.98 hr	9.0 lbs/ft^3	0.75 fl. oz./sk.	3-1/4"	6.7%	64°
5 fl. oz./sk.	9.95 hr	9.0 lbs/ft^3	0.75 fl. oz./sk.	3-1/4"	6.5%	64°

TABLE 2

PROTEX PDA 25R @ 50°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
4 fl. oz./sk.	9.90 hrs	9.3 lbs./ft^3	.60 fl. oz./sk.	2-3/4"	6.4%	70°F.

PLASTIMENT @ 50°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	12.90 hrs	9.0 lbs./ft^3	.70 fl. oz./sk.	2-1/2"	6.4%	70°F.

PROTEX PDA 25R @ 60°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
4 fl. oz./sk.	8.20 hrs	9.3 lbs./ft^3	.60 fl. oz./sk.	2-3/4"	5.7%	67°F.

PLASTIMENT @ 60°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	9.96 hrs	9.0 lbs./ft^3	.60 fl. oz./sk.	3-1/2"	6.0%	68°F.

TABLE 3

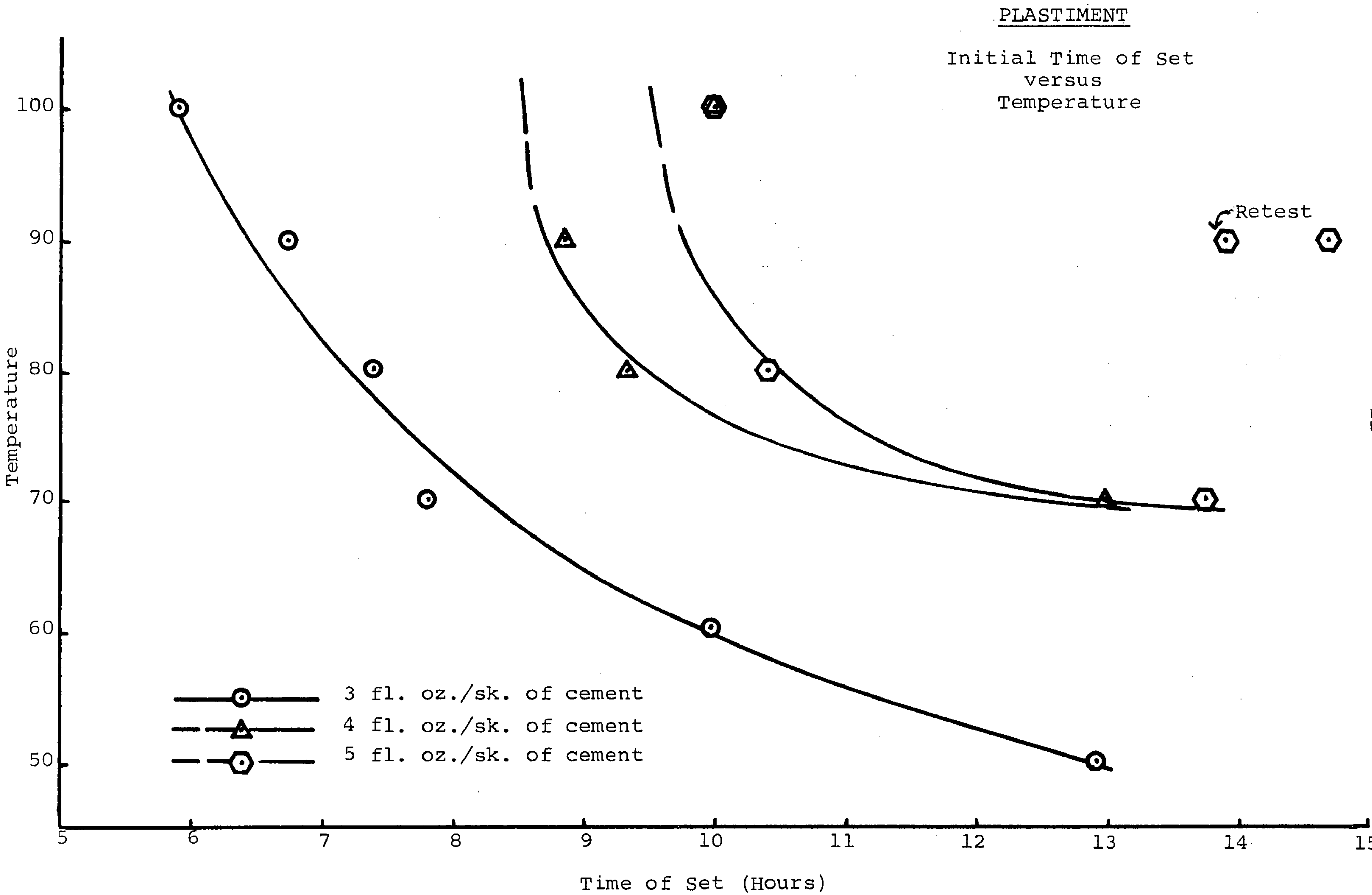

PLASTIMENT
Initial Time of Set
versus
Temperature
Retest
Temperature
100
90
80
70
60
50
5
6
7
8
9
10
11
12
13
14
15
3 fl. oz./sk. of cement
4 fl. oz./sk. of cement
5 fl. oz./sk. of cement
Time of Set (Hours)

Figure 2

PROTEX PDA-25R

70°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
4 fl. oz./sk.	7.58 hr	9.6 lbs./ft^3	0.65 fl. oz./sk	2-3/4"	6.0%	69°
5 fl. oz./sk.	8.22 hr	9.4 lbs./ft^3	0.60 fl. oz./sk	2-1/2"	5.7%	68°
6 fl. oz./sk.	8.71 hr	9.9 lbs./ft^3	0.30 fl. oz./sk	2-3/4"	4.6%	70°

80°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
4 fl. oz./sk.	7.00 hr	9.3 lbs./ft^3	0.30 fl. oz./sk	3"	6.0%	78°
5 fl. oz./sk.	8.67 hr	9.3 lbs./ft^3	0.30 fl. oz./sk	3-1/2"	6.2%	78°
6 fl. oz./sk.	9.10 hr	9.1 lbs./ft^3	0.30 fl. oz./sk	3-1/2"	6.6%	78°

90°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
4 fl. oz./sk.	5.78 hr	9.3 lbs./ft^3	0.30 fl. oz./sk	3"	6.0%	65°
5 fl. oz./sk.	5.81 hr	9.1 lbs./ft^3	0.25 fl. oz./sk	2-3/4"	5.7%	65°
6 fl. oz./sk.	8.57 hr	9.3 lbs./ft^3	0.20 fl. oz./sk	3-1/4"	5.4%	65°

100°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
4 fl. oz./sk.	5.22 hr	9.3 lbs./ft^3	0.30 fl. oz./sk	2-3/4"	6.0%	64°
5 fl. oz./sk.	6.22 hr	9.1 lbs./ft^3	0.30 fl. oz./sk	3"	6.4%	64°
6 fl. oz./sk.	6.62 hr	9.1 lbs./ft^3	0.30 fl. oz./sk	3-1/2"	6.8%	64°

TABLE 4

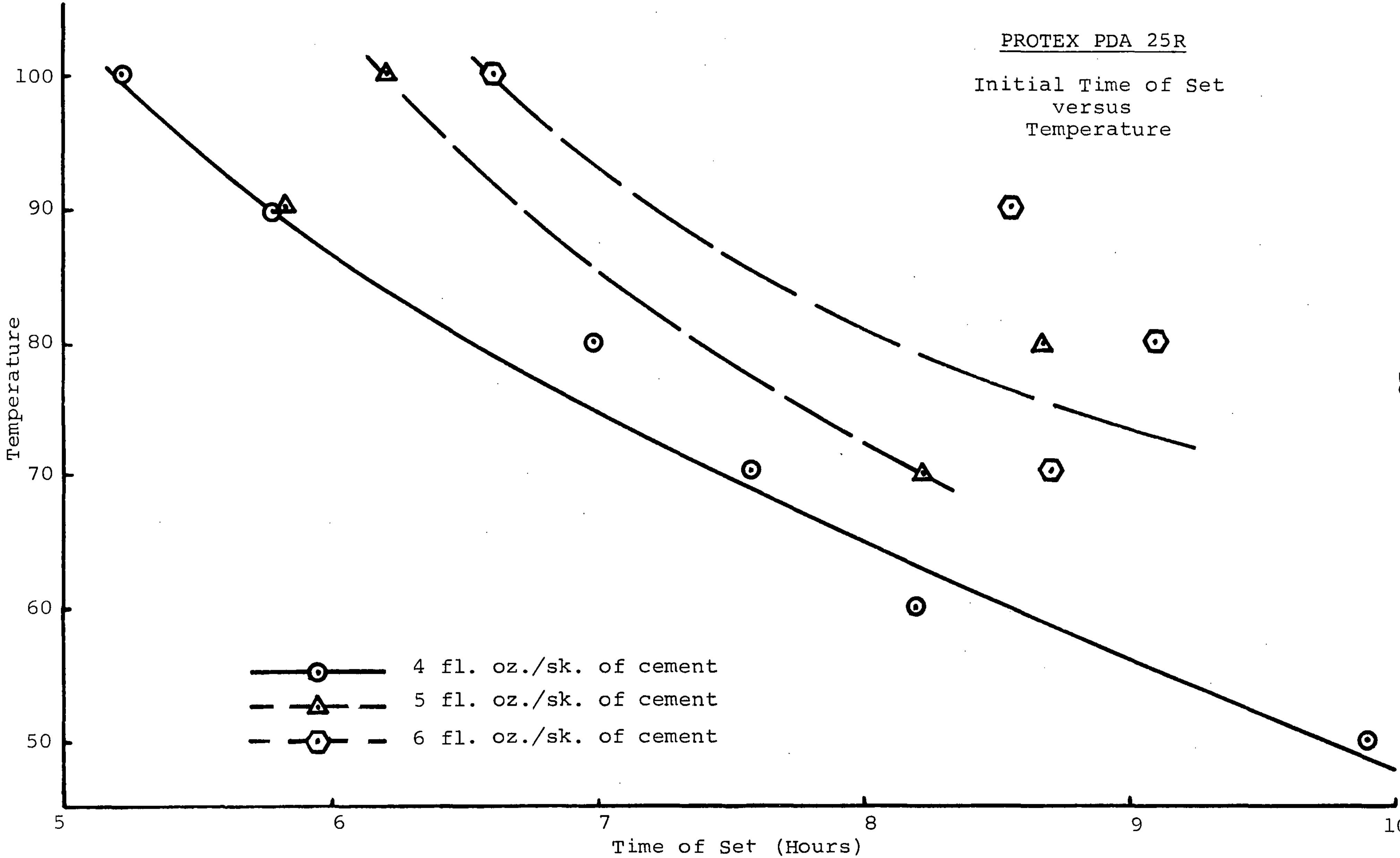

PROTEX PDA 25R
Initial Time of Set versus Temperature
Temperature
100
90
80
70
60
50
5
6
7
8
9
10
Time of Set (Hours)
4 fl. oz./sk. of cement
5 fl. oz./sk. of cement
6 fl. oz./sk. of cement

Figure 3

POZZOLITH 100XR

70°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./100#	11.72 hr	9.6 lbs./ft^3	0.65 fl. oz./sk	2-3/4"	5.8%	72°
4 fl. oz./100#	12.79 hr	9.4 lbs./ft^3	0.60 fl. oz./sk	2-3/4"	5.8%	72°
5 fl. oz./100#	14.86 hr	9.3 lbs./ft^3	0.60 fl. oz./sk	2-3/4"	6.2%	72°

80°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./100#	8.67 hr	9.3 lbs./ft^3	0.60 fl. oz./sk	2-1/2"	6.0%	70°
4 fl. oz./100#	11.32 hr	9.3 lbs./ft^3	0.70 fl. oz./sk	2-1/2"	6.4%	70°
5 fl. oz./100#	16.50 hr	8.9 lbs./ft^3	0.75 fl. oz./sk	3-1/2"	6.6%	76°

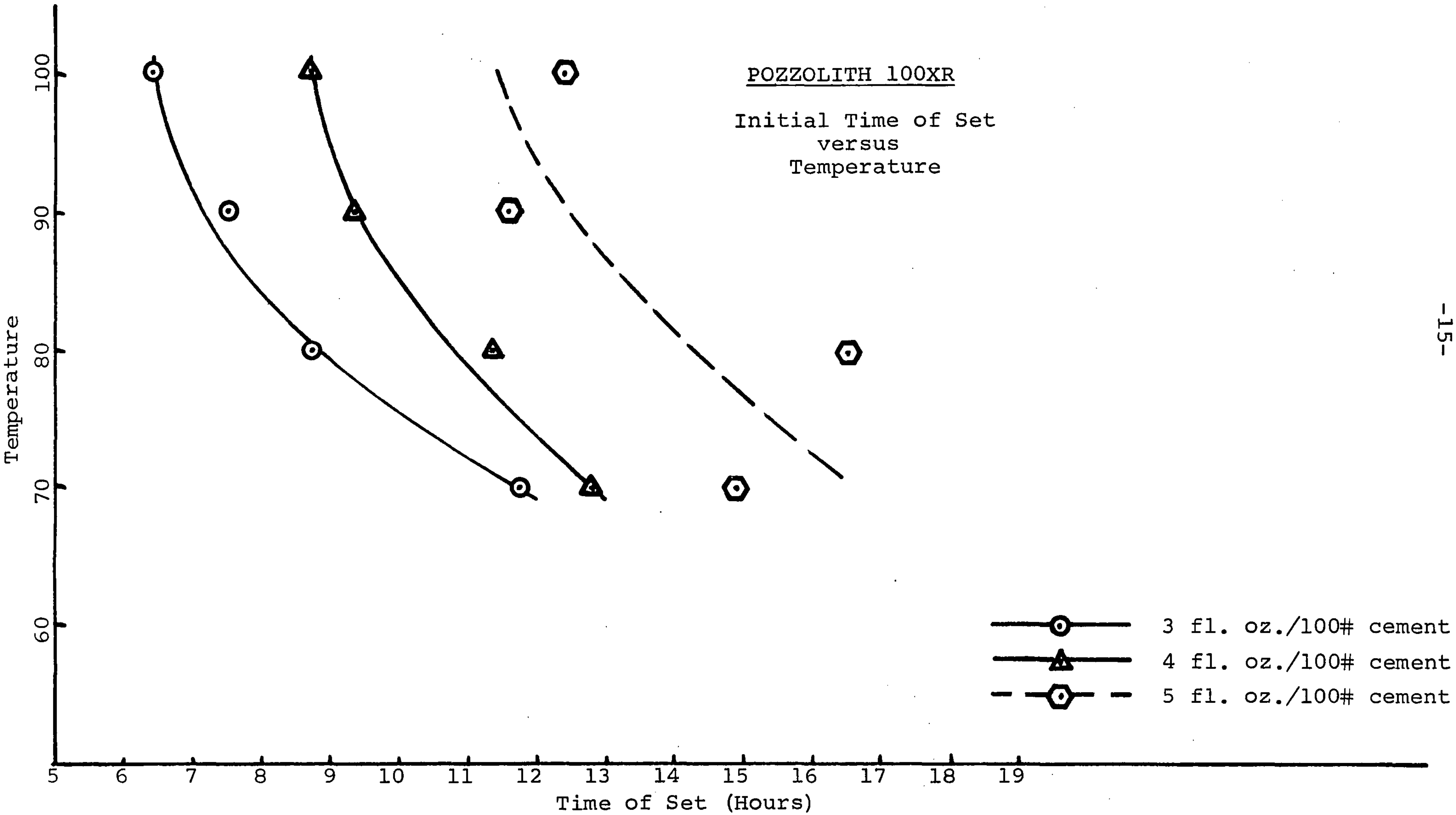
90°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./100#	7.47 hr	8.9 lbs/ft^3	0.75 fl. oz./sk	2-3/4"	6.5%	64°
4 fl. oz./100#	9.32 hr	9.1 lbs/ft^3	0.75 fl. oz./sk	3"	6.4%	64°
5 fl. oz./100#	11.56 hr	9.4 lbs/ft^3	0.75 fl. oz./sk	3"	6.4%	68°

100°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./100#	6.4 hr	9.4 lbs/ft^3	0.75 fl. oz./sk	2-3/4"	6.6%	68°
4 fl. oz./100#	8.72 hr	9.3 lbs/ft^3	0.75 fl. oz./sk	2-1/2"	6.8%	68°
5 fl. oz./100#	12.40 hr	9.3 lbs/ft^3	0.50 fl. oz./sk	3"	5.4%	68°

TABLE 5



POZZOLITH 100XR
Initial Time of Set
versus
Temperature
Temperature
100
90
80
70
60
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
3 fl. oz./100# cement
4 fl. oz./100# cement
5 fl. oz./100# cement
Time of Set (Hours)

Figure 4

DARATARD 17

70°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	10.40 hr	9.4 lbs/ft^3	0.65 fl. oz./sk.	3"	5.8%	72°
4 fl. oz./sk.	11.97 hr	9.4 lbs/ft^3	0.55 fl. oz./sk.	3-1/4"	5.4%	71°
5 fl. oz./sk.	12.20 hr	9.1 lbs/ft^3	0.45 fl. oz./sk.	3"	5.4%	70°

80°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	7.67 hr	9.7 lbs/ft^3	0.60 fl. oz./sk.	3"	6.2%	78°
4 fl. oz./sk.	9.21 hr	9.3 lbs/ft^3	0.50 fl. oz./sk.	3"	5.5%	78°
5 fl. oz./sk.	10.47 hr	9.7 lbs/ft^3	0.45 fl. oz./sk.	3"	5.3%	78°

90°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	7.55 hr	9.1 lbs/ft^3	0.45 fl. oz./sk.	2-3/4"	6.1%	65°
4 fl. oz./sk.	10.23 hr	9.0 lbs/ft^3	0.50 fl. oz./sk.	2-3/4"	6.6%	65°
5 fl. oz./sk.	12.34 hr	9.0 lbs/ft^3	0.60 fl. oz./sk.	3-1/2"	7.6%	65°

100°F

DOSAGE OF RETARDER	TIME OF SET	WATER USED	AD-AIRE RATE	SLUMP	AIR CONTENT	TEMP. OF MIX
3 fl. oz./sk.	6.11 hr	9.3 lbs/ft^3	0.75 fl. oz./sk.	2-3/4"	5.3%	74°
4 fl. oz./sk.	6.50 hr	9.6 lbs/ft^3	0.75 fl. oz./sk.	2-1/2"	5.3%	74°
5 fl. oz./sk.	8.53 hr	9.6 lbs/ft^3	0.65 fl. oz./sk.	2-3/4"	5.6%	72°

TABLE 6

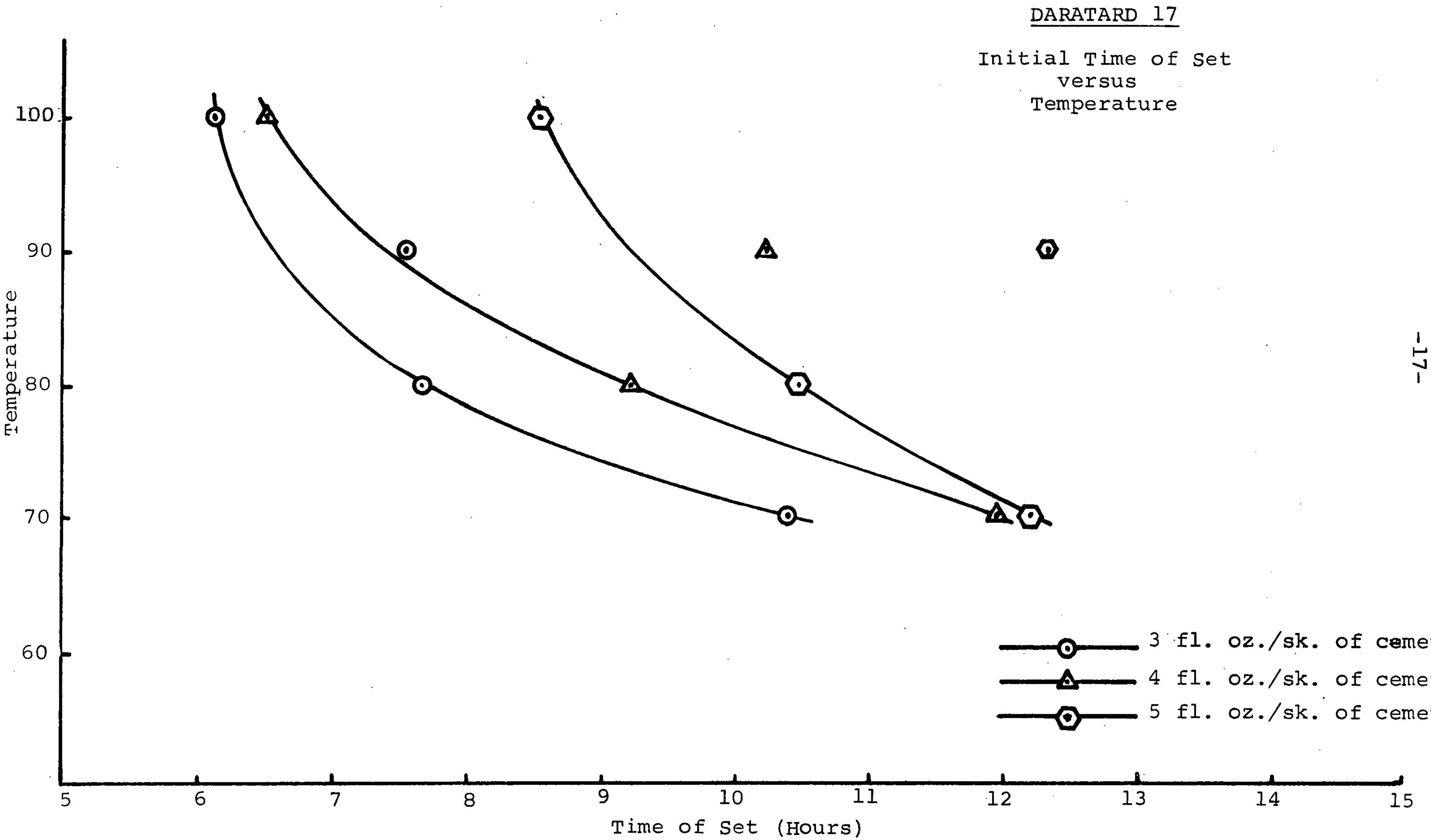

DARATARD 17
Initial Time of Set
versus
Temperature
100
90
80
70
60
Temperature
5
6
7
8
9
10
11
12
13
14
15
Time of Set (Hours)
3 fl. oz./sk. of ceme
4 fl. oz./sk. of ceme
5 fl. oz./sk. of ceme

Figure 5

PER CENT RETARDATION

Plastiment

	70°	80°	90°	100°
3 fl. oz./sk.	59%	81%	72%	64%
4 fl. oz./sk.	165%	128%	104%	177%
5 fl. oz./sk.	180%	155%	273%	176%
			*252%	

*Retest

Protex PDA 25R

	70°	80°	90°	100°
4 fl. oz./sk.	54%	72%	47%	45%
5 fl. oz./sk.	68%	113%	48%	73%
6 fl. oz./sk.	78%	123%	118%	84%

Pozzolith 100XR

	70°	80°	90°	100°
3 fl. oz./100#	139%	113%	90%	78%
4 fl. oz./100#	161%	177%	137%	142%
5 fl. oz./100#	203%	304%	194%	244%

Daratard 17

	70°	80°	90°	100°
3 fl. oz./sk.	112%	88%	92%	70%
4 fl. oz./sk.	144%	126%	168%	81%
5 fl. oz./sk.	149%	157%	214%	137%

TABLE 7

6.0 DISCUSSION OF RESULTS

When studying the results listed in Section 5.2, Tabulations of Results, the valid comparisons can only be made between mixes with similar air contents, slumps, and mix temperatures. Trying to compensate for high air contents, large slumps, and low mix temperatures, which all cause more retardation, does not yield consistent data. For this reason, only the information which gives valid comparisons will be interpreted.

All control mixes listed in Table 1 are valid data. The information produced an acceptable curve in Figure 1. The curve shows the rate of retardation increasing as the temperature decreases. For example, the retardation between 80° and 70° F. increased 0.82 hours but between 60° and 50° F. the retardation increased 1.99 hours.

The Plastiment retarder appeared to be unaffected by mix temperature at the normal dosage rate of 3 fl. oz./sk. in the full curing temperature range of 50° to 100° F. However the higher dosage rates, 4 and 5 fl. oz./sk., produced erratic results and were apparently more affected by the mix temperature variation. The 5 fl. oz./sk. mix at 90° F. cure has an unexplainable time of set. A retest verified the original 14.65 hour time of set. The higher dosage rates did not affect the air contents as the Ad-Aire dosage rate was held constant. No water reduction properties were apparent as the dosage rate increased.

Protex PDA 25R produced the normal, expected time of set curves for the 4 fl. oz./sk. dosage. Dosage rates above this appeared to affect the air content. The Ad-Aire dosage rate at higher retarder dosage rates must be decreased to maintain the correct air content. The amount of water needed to produce the correct slump did not change as the dosage rate increased.

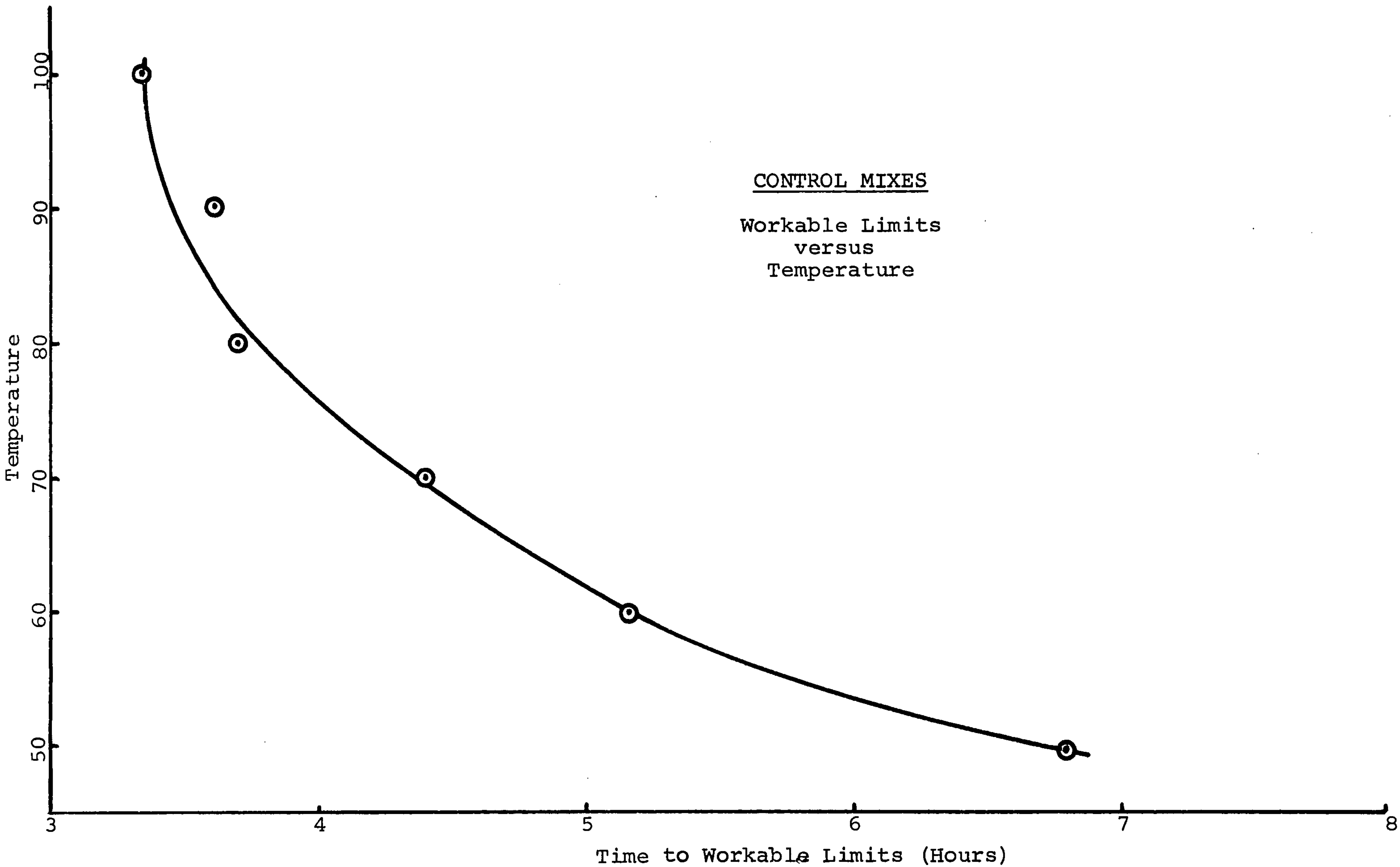
The temperatures of the mixes with this retarder varied considerably. The 100° F. cure mix had the low mix temperature of 64° F. The 80° F. cure mix had the high mix temperature of 78°. When comparing the data from this retarder, the 80° F. cure temperature data should be excluded. The other three temperatures had mix temperatures in the same range and can be used for comparisons.

Pozzolith 100XR produced uniform curves for the 3 and 4 fl. oz./100# cement dosage rate. The 5 fl. oz./100# dosage rate produced unpredictable times of set. At the two lower dosage rates, variations in the temperature of the mix did not seem to affect the expected time of set. The 5 fl. oz./100# cement had variations in air content and slump which would make this data questionable. For example, the 80° F. high dosage rate had a slump of 3.5 inches which may have caused the 80° F. time of set to be longer than the 70° time of set. Increases in retarder dosage rates did not necessitate a change in the Ad-Aire rate. The retarder did have a water reducing property as the retarder dosage rate increased.

Daratard 17 retarder produced the expected curves for all three dosage rates. The 90° F. cure temperature information was excluded as explained in Section 5.2. Excluding the 90° F. mixes, the Ad-Aire rate had to be decreased as the retarder dosage increased. No change in water demand was evident as the dosage rate increased.

When using a retarded concrete on a bridge deck and the initial time of set has been reached, any further movement of the concrete, such as vibration, would cause cracking. Therefore, a new term "workable limits" must be defined. The workable limit definition would be the time from mixing of the concrete to the time when concrete could no longer be flexed without producing cracking.

Hairline cracking would occur during the penetration resistance test near 250 PSI. These cracks would occur between the penetration test holes. Therefore, an arbitrary value for the time to workable limit will be set as the time to reach 235 PSI. Figures 7 to 11 are graphs showing the time to reach the workable limits for the controls and retarded admixtures. These curves can be applied to field applications to determine the actual time a bridge deck can be "worked" before harmful structural cracking occurs.


CONTROL MIXES
Workable Limits
versus
Temperature
Temperature
100
90
80
70
60
50
3
4
5
6
7
8
Time to Workable Limits (Hours)
Figure 7

PLASTIMENT

Workable Limits
versus
Temperature

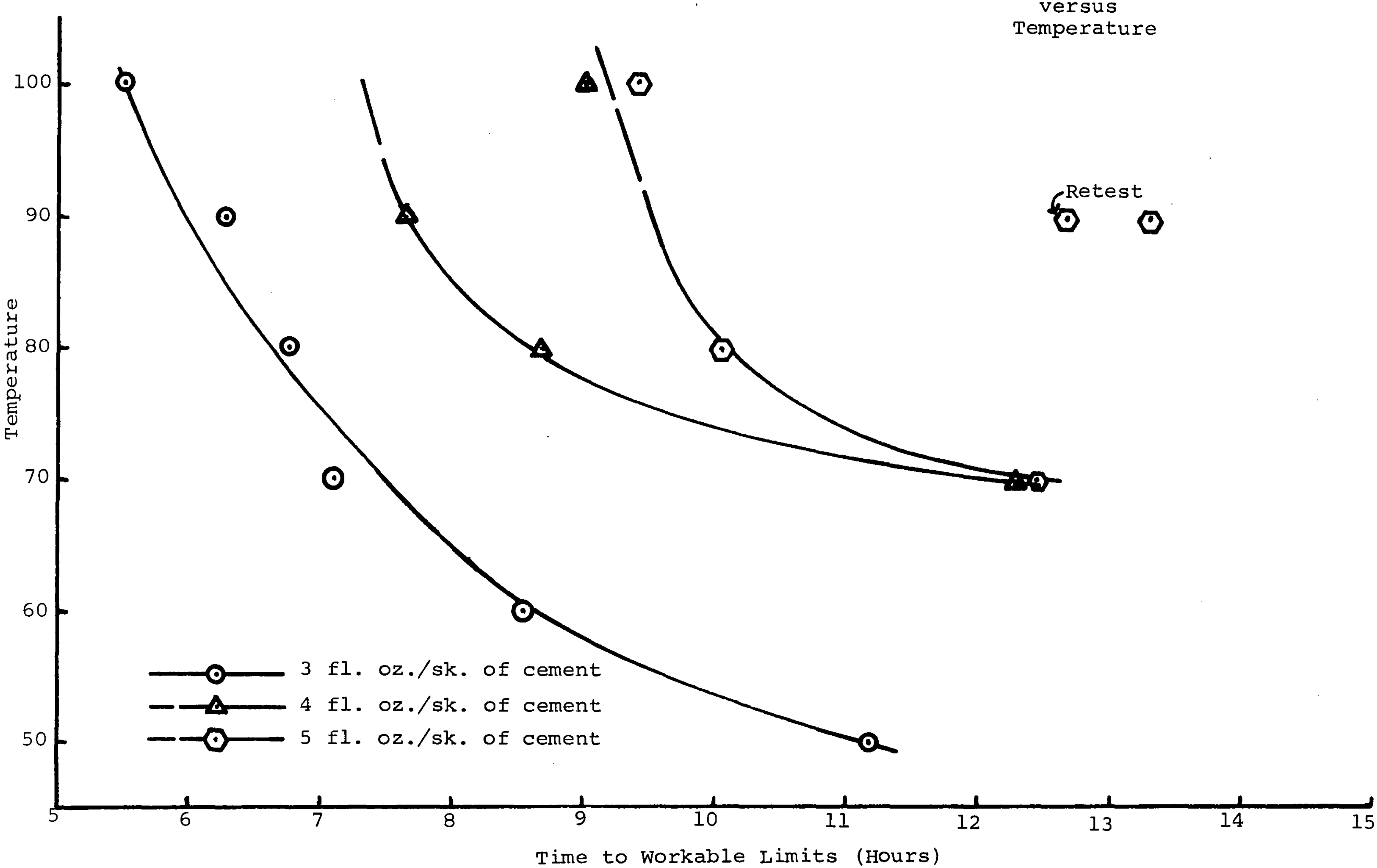
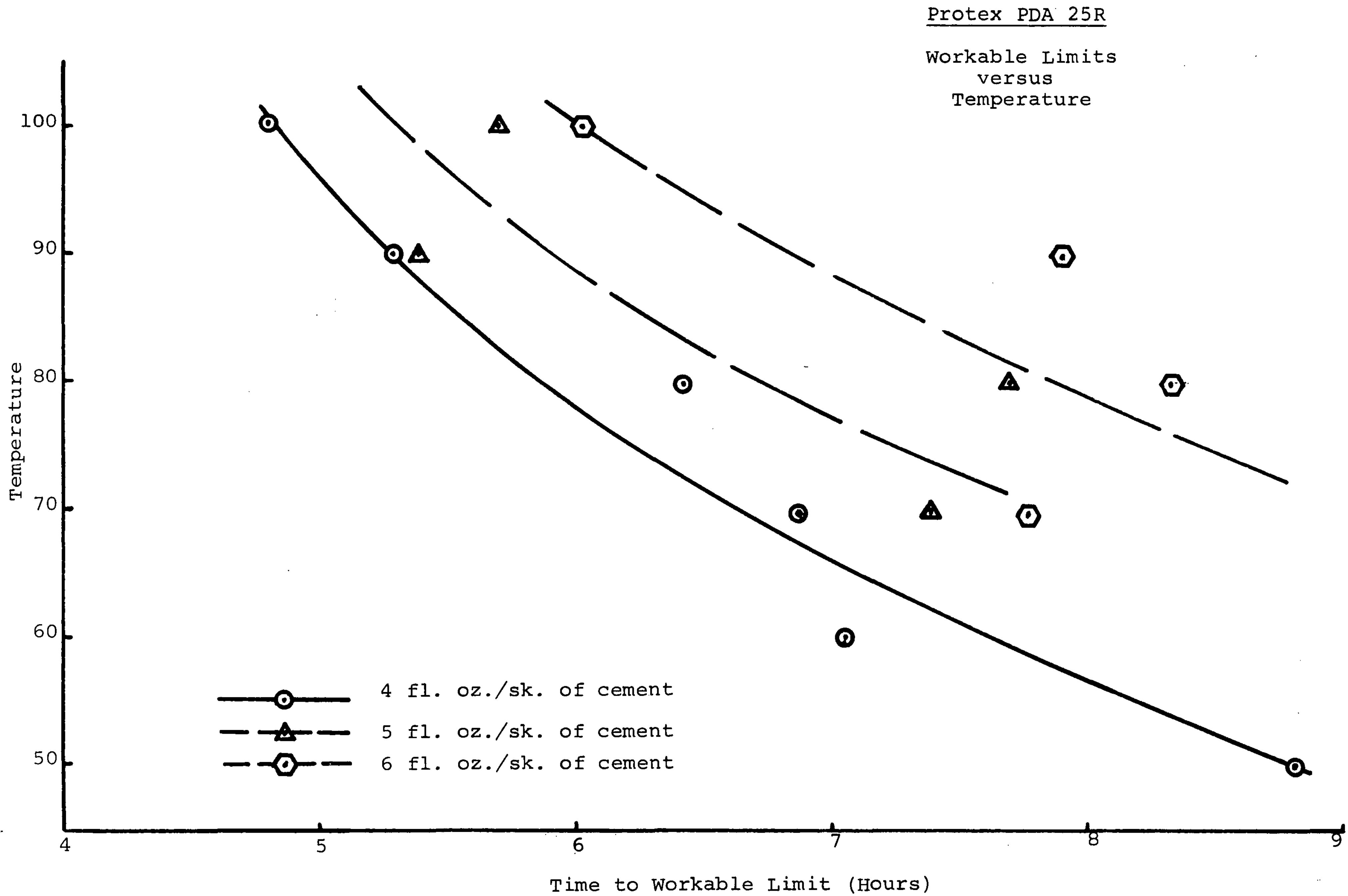
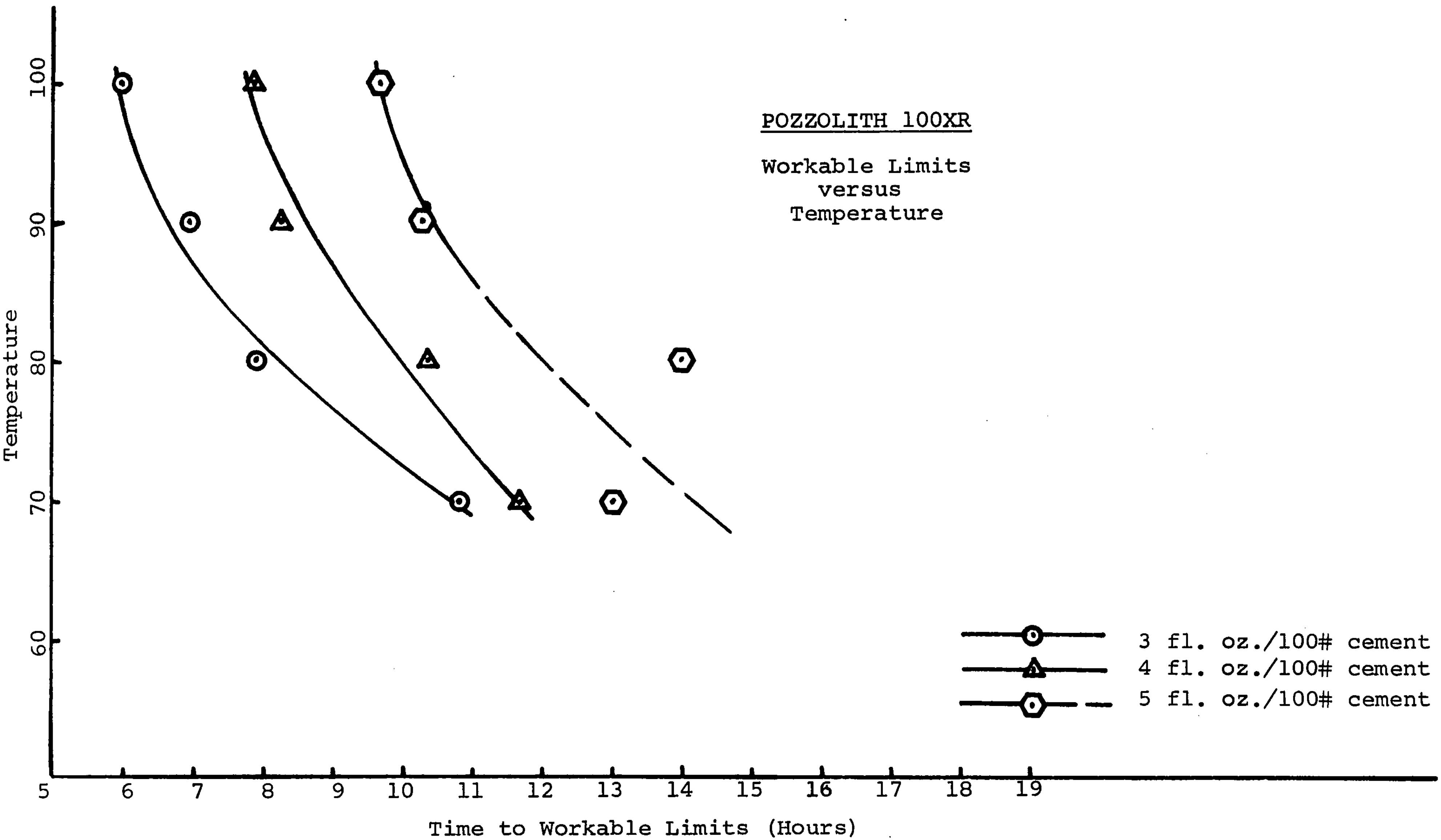


Figure 8



Protex PDA 25R
Workable Limits
versus
Temperature
Temperature
100
90
80
70
60
50
4
5
6
7
8
9
4 fl. oz./sk. of cement
5 fl. oz./sk. of cement
6 fl. oz./sk. of cement
Time to Workable Limit (Hours)

Figure 9



POZZOLITH 100XR
Workable Limits
versus
Temperature
Temperature
100
90
80
70
60
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
3 fl. oz./100# cement
4 fl. oz./100# cement
5 fl. oz./100# cement
Time to Workable Limits (Hours)

Figure 10

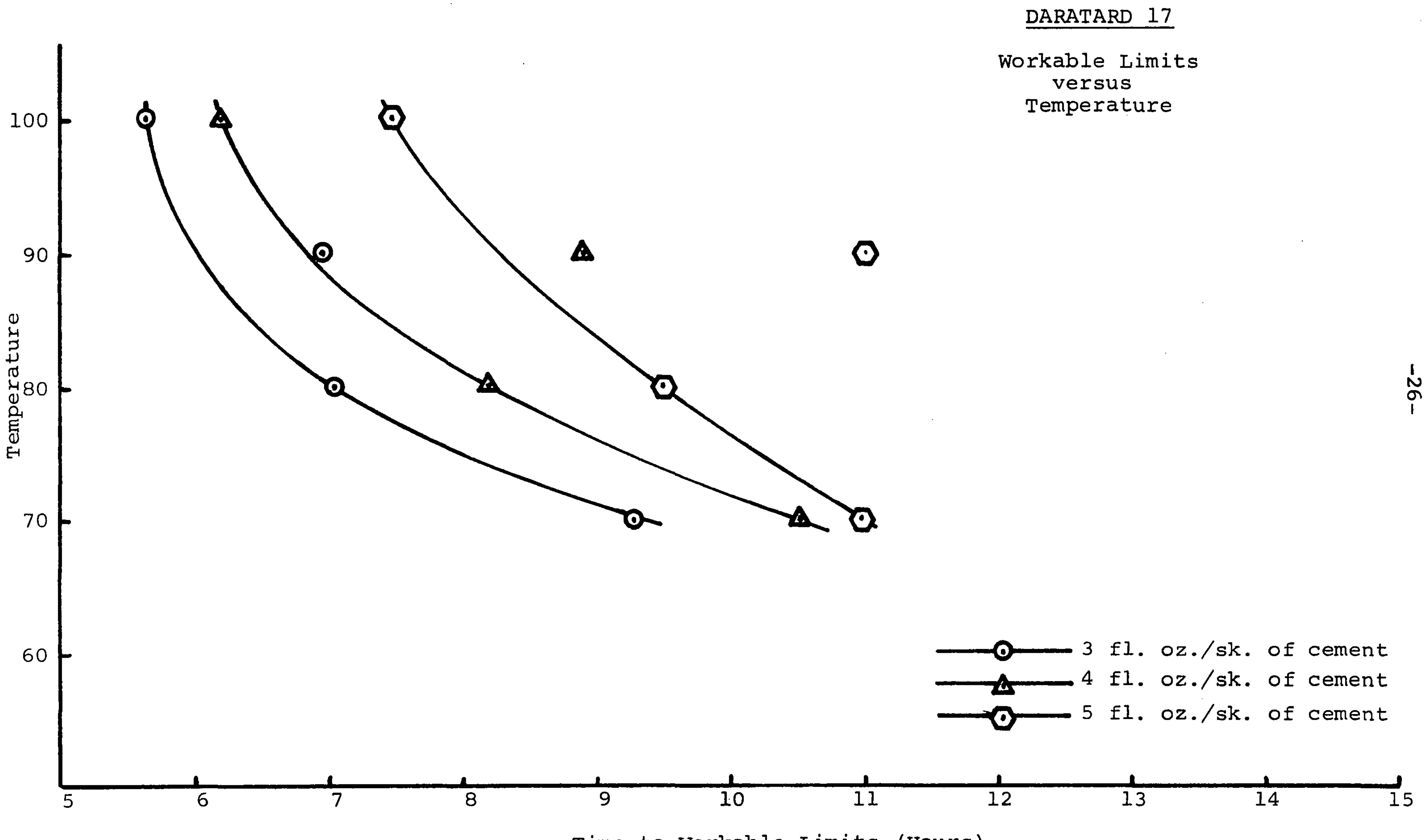

DARATARD 17
Workable Limits
versus
Temperature
Temperature
100
90
80
70
60
5
6
7
8
9
10
11
12
13
14
15
Time to Workable Limits (Hours)
3 fl. oz./sk. of cement
4 fl. oz./sk. of cement
5 fl. oz./sk. of cement

Figure 11

7.0 CONCLUSIONS

The following conclusions can be drawn from this report for application on field projects:

1. The manufacturer's recommend dosage rate (lowest rate used in each case) produced the most consistent and predictable time of sets.

2. High dosage rates do not yield consistent results. Changes in slump, air, temperature, etc. have a much more drastic effect on higher dosage rates than the lower rates.

3. The initial time of set is affected by changes in air content and slump even though both are within specification limits. Therefore, tight controls for bridge inspections must be maintained.

4. The "workable limits" of concrete is a useful tool to construction personnel to determine the time when concrete can no longer be flexed without producing cracking.

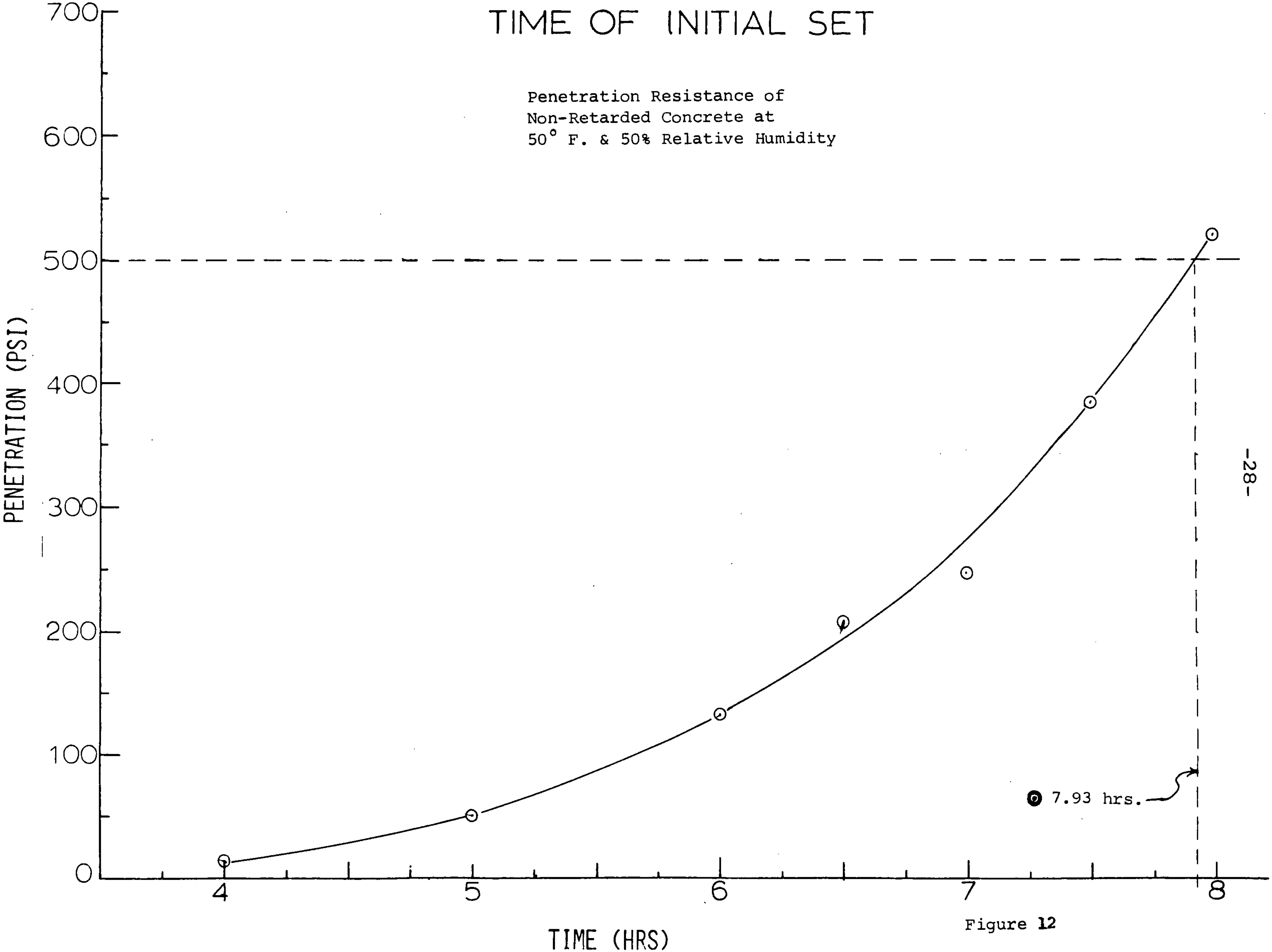

TIME OF INITIAL SET
Penetration Resistance of
Non-Retarded Concrete at
50° F. & 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
4
5
6
7
8
TIME (HRS)
7.93 hrs.

Figure 12

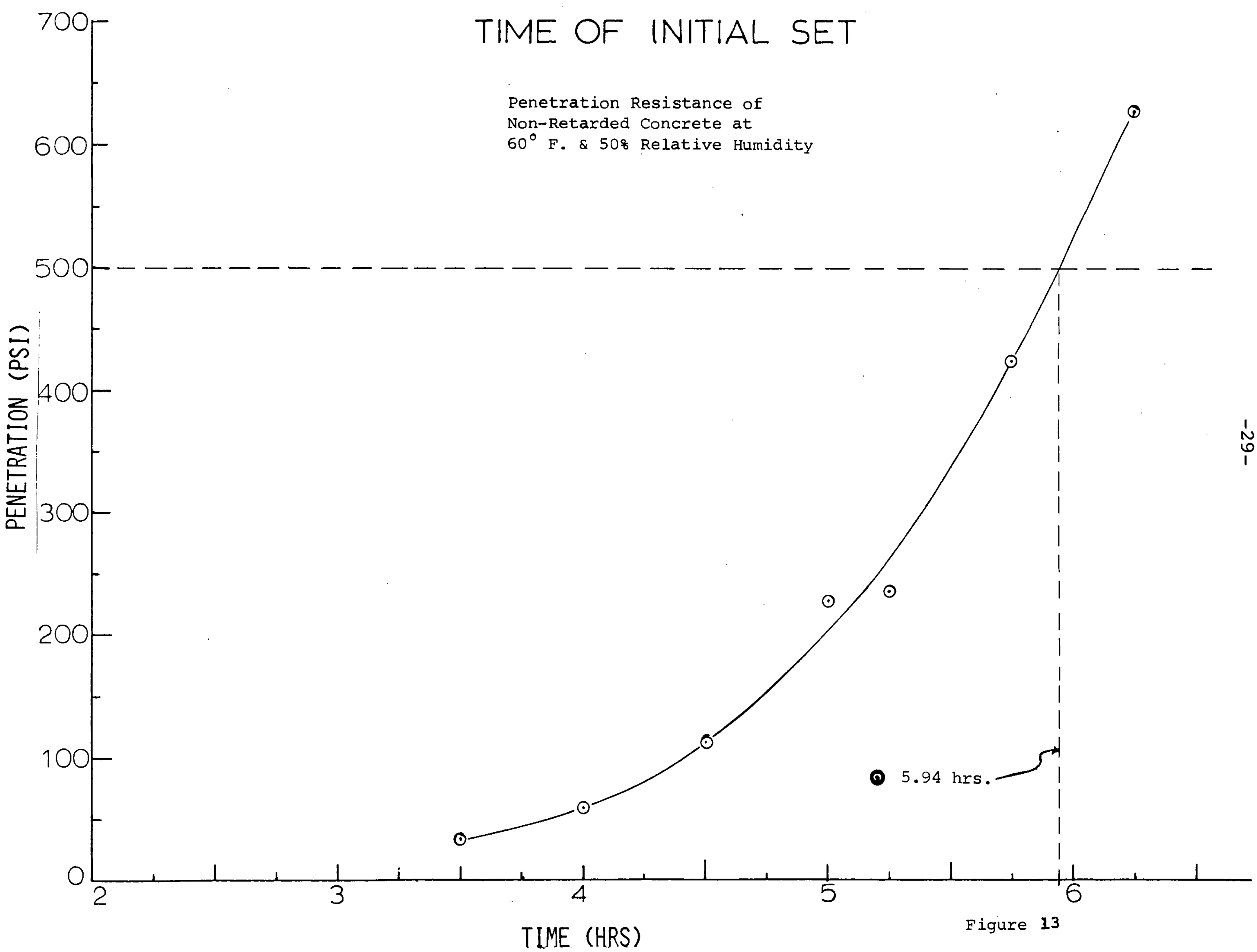

TIME OF INITIAL SET
Penetration Resistance of
Non-Retarded Concrete at
60° F. & 50% Relative Humidity
700
600
500
400
300
200
100
0
PENETRATION (PSI)
2
3
4
5
6
TIME (HRS)
5.94 hrs.

Figure 13

TIME OF INITIAL SET

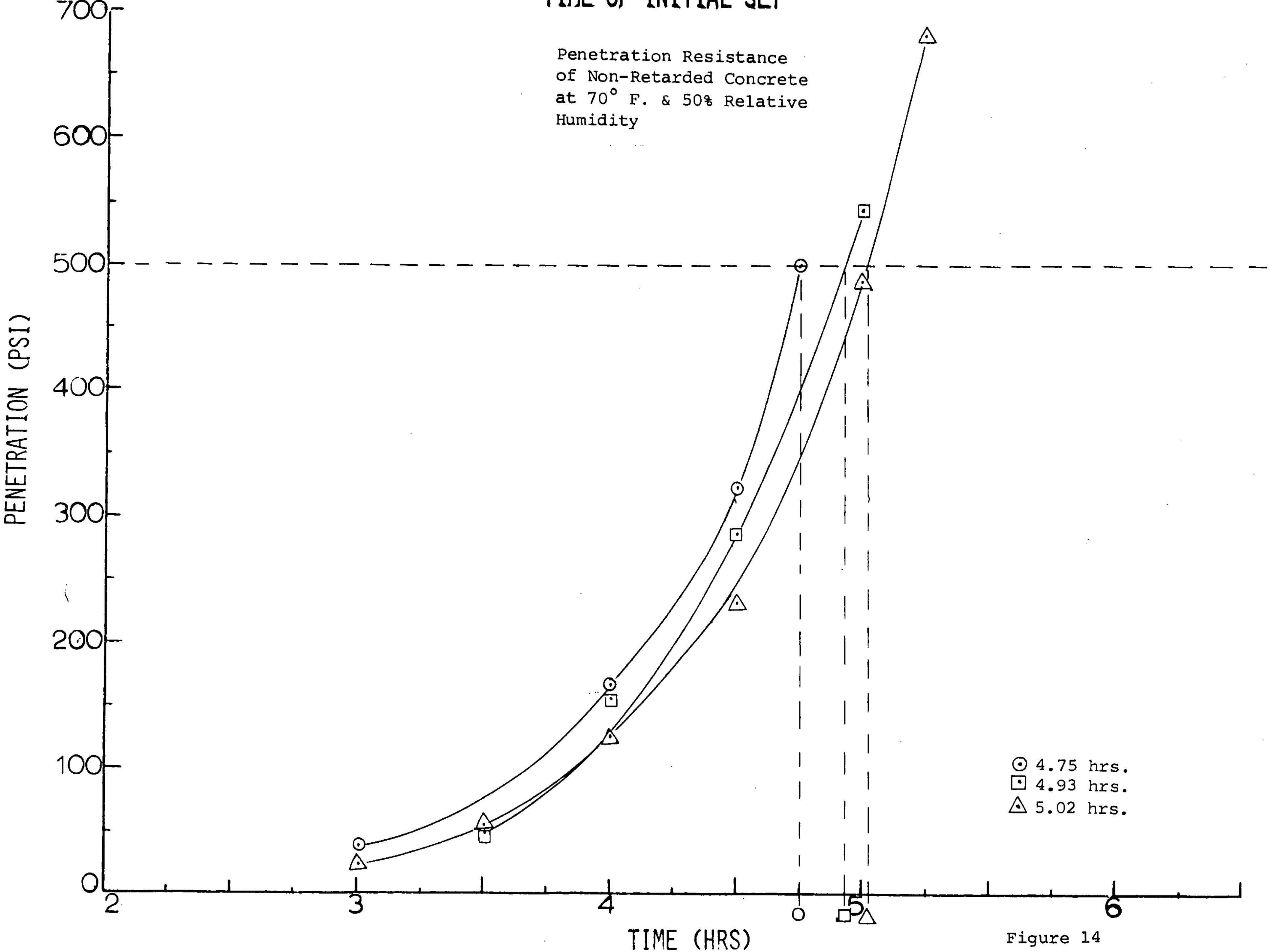
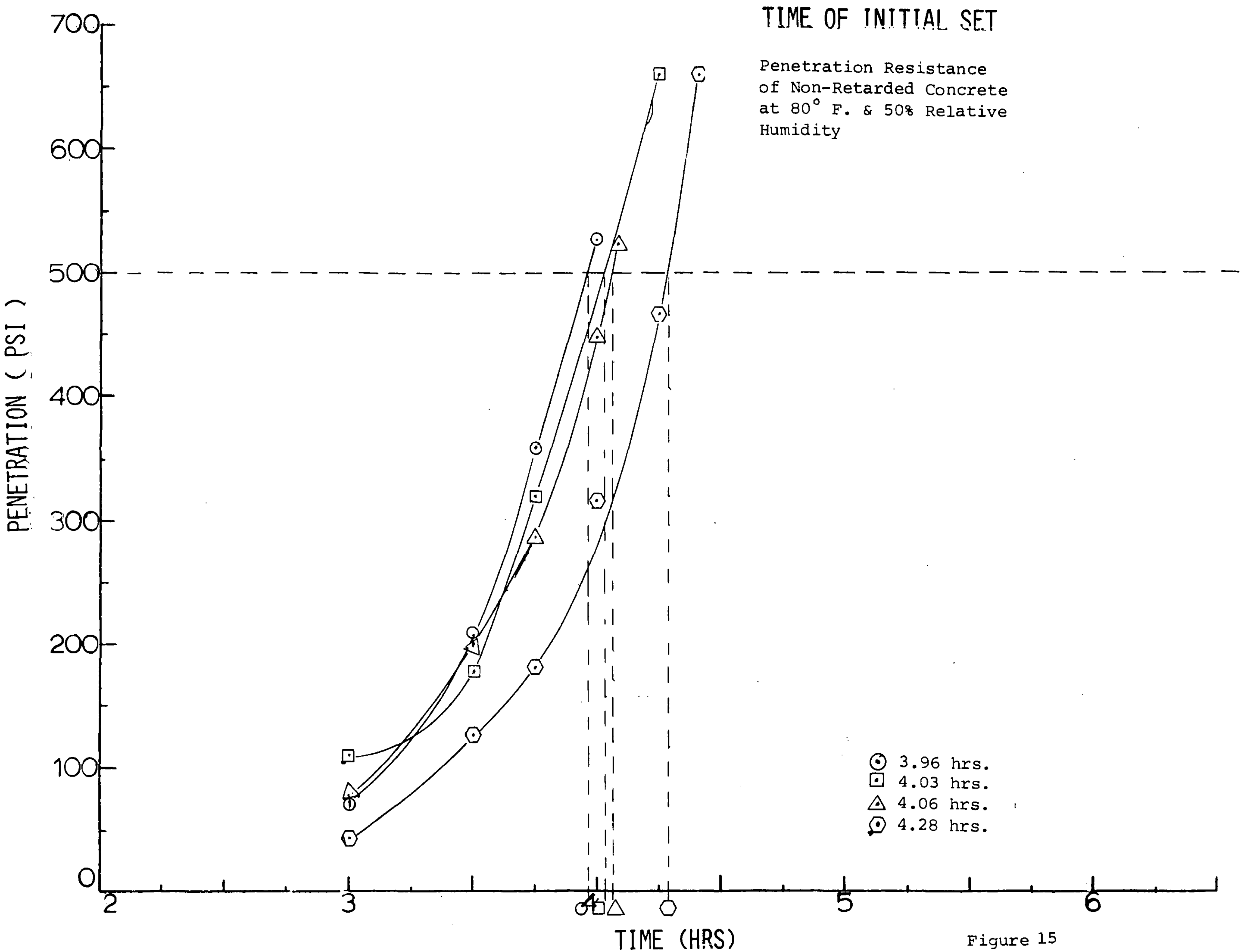


Figure 14



TIME OF INITIAL SET
Penetration Resistance of Non-Retarded Concrete at 80° F. & 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
2
3
4
5
6
TIME (HRS)
3.96 hrs.
4.03 hrs.
4.06 hrs.
4.28 hrs.

Figure 15

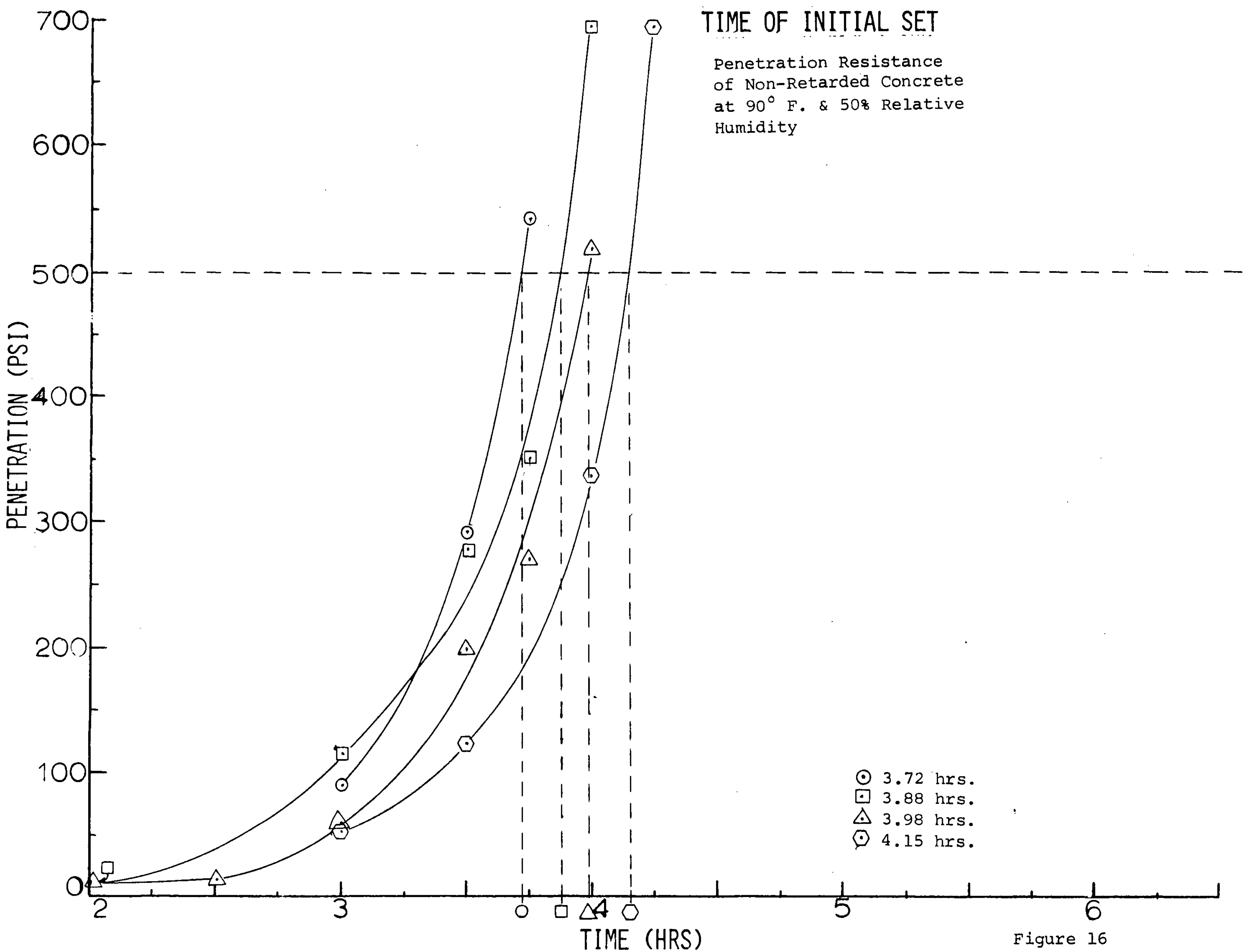
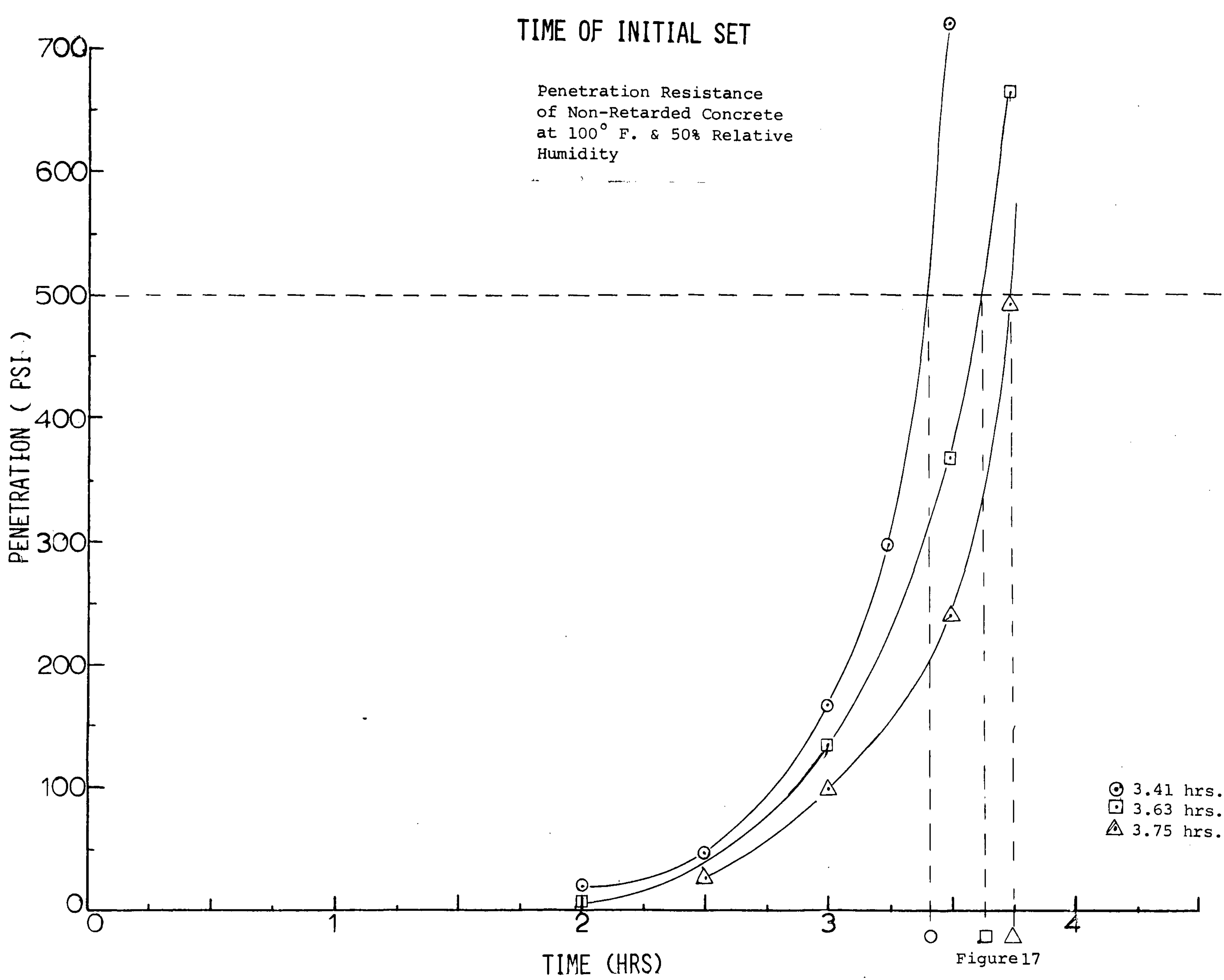

TIME OF INITIAL SET
Penetration Resistance of Non-Retarded Concrete at 90° F. & 50% Relative Humidity
PENETRATION (PSI)
0
100
200
300
400
500
600
700
TIME (HRS)
2
3
4
5
6
3.72 hrs.
3.88 hrs.
3.98 hrs.
4.15 hrs.

Figure 16



TIME OF INITIAL SET
Penetration Resistance of Non-Retarded Concrete at 100° F. & 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
0
1
2
3
4
TIME (HRS)
3.41 hrs.
3.63 hrs.
3.75 hrs.

Figure 17

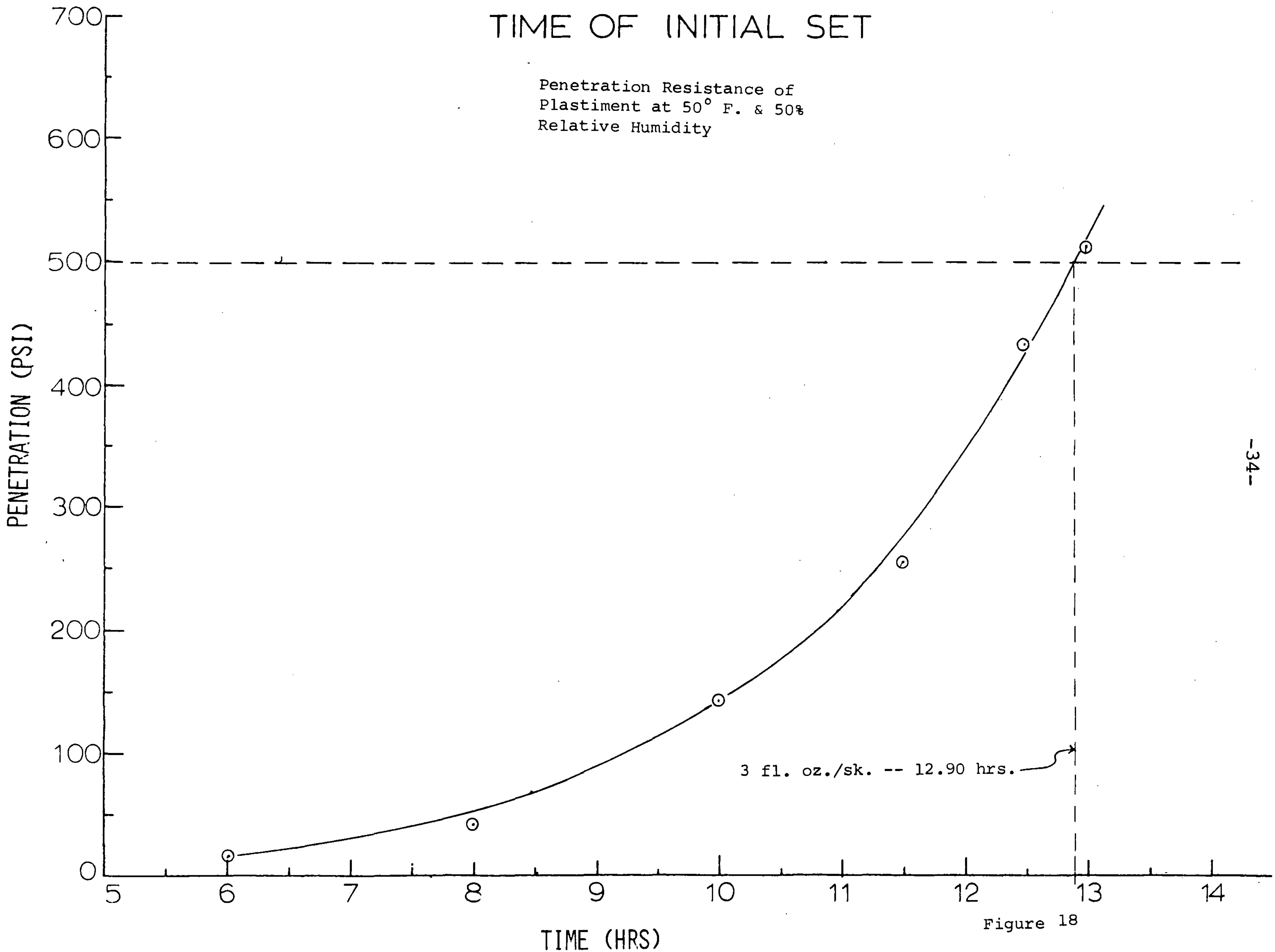

TIME OF INITIAL SET
Penetration Resistance of
Plastiment at 50° F. & 50%
Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
5
6
7
8
9
10
11
12
13
14
3 fl. oz./sk. -- 12.90 hrs.
TIME (HRS)

Figure 18

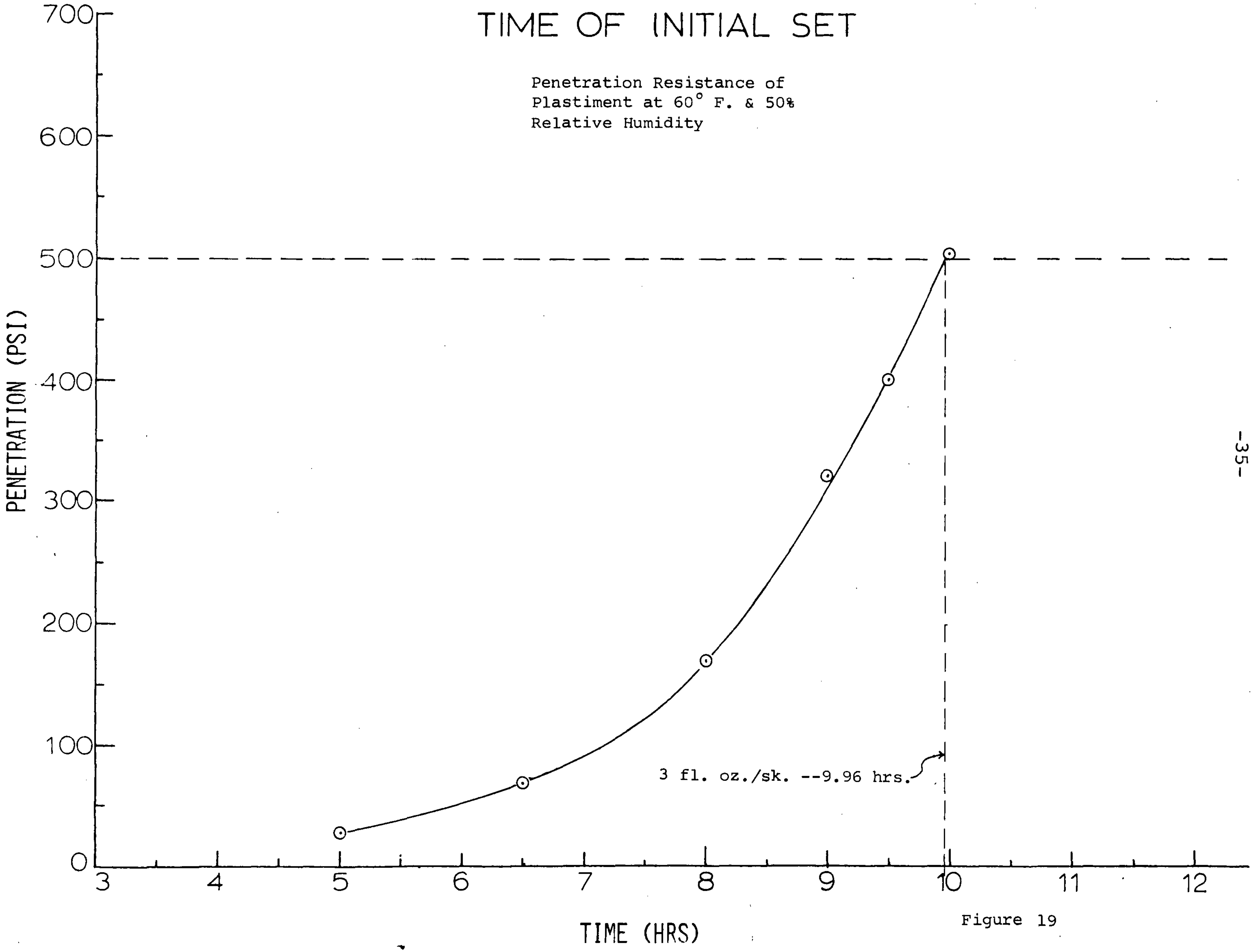

TIME OF INITIAL SET
Penetration Resistance of
Plastiment at 60° F. & 50%
Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
3
4
5
6
7
8
9
10
11
12
3 fl. oz./sk. --9.96 hrs.
TIME (HRS)

Figure 19

TIME OF INITIAL SET

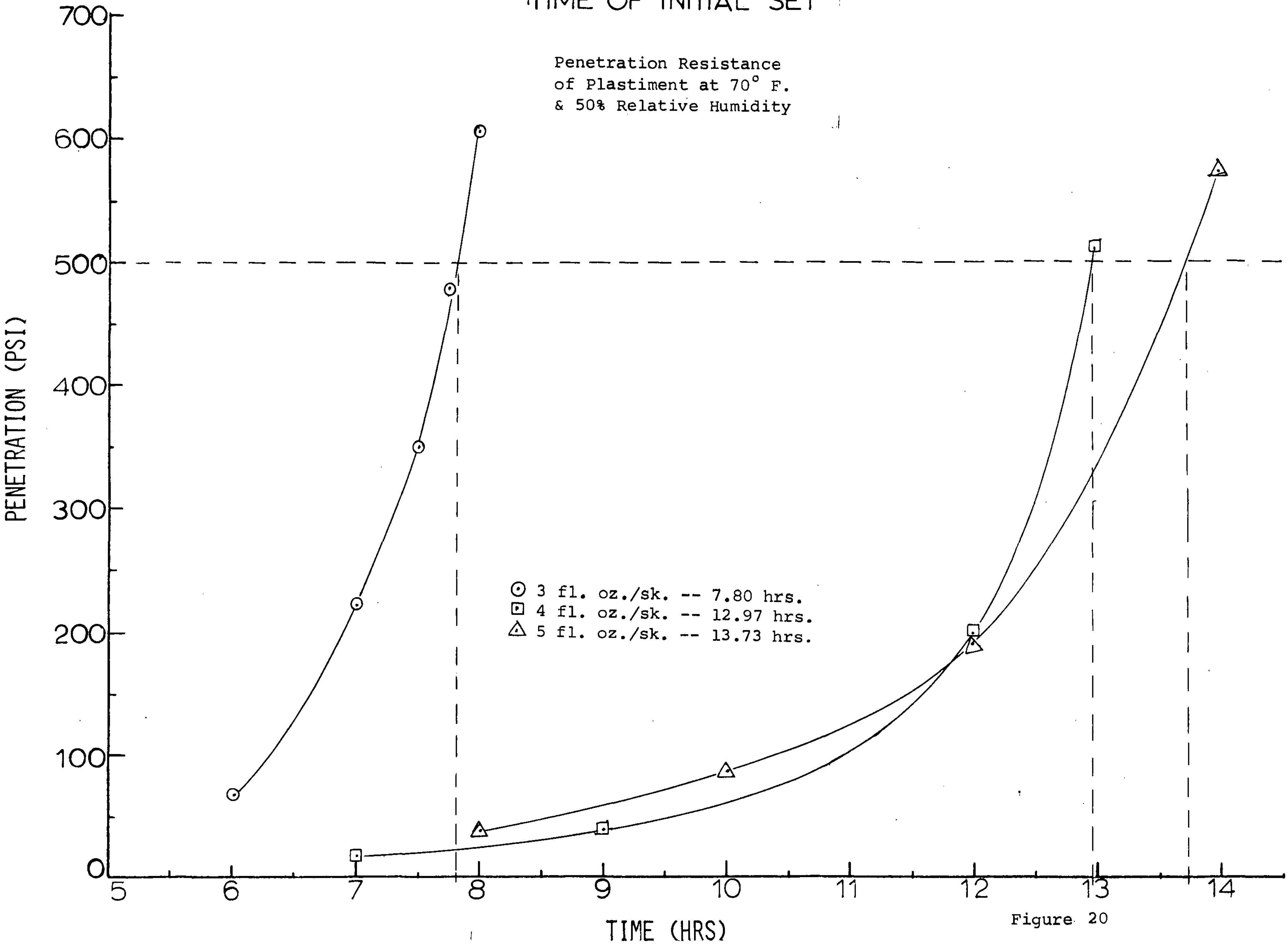
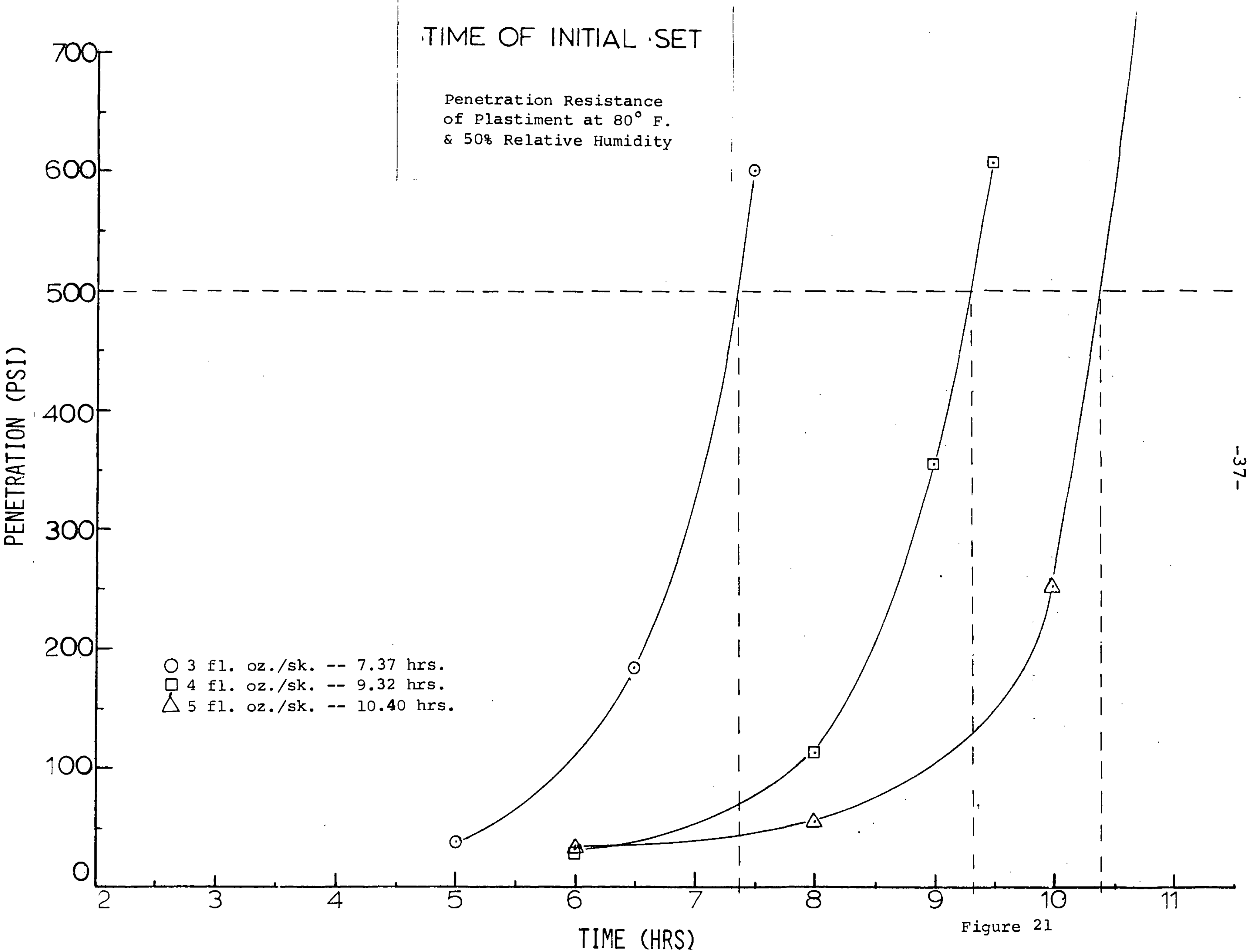
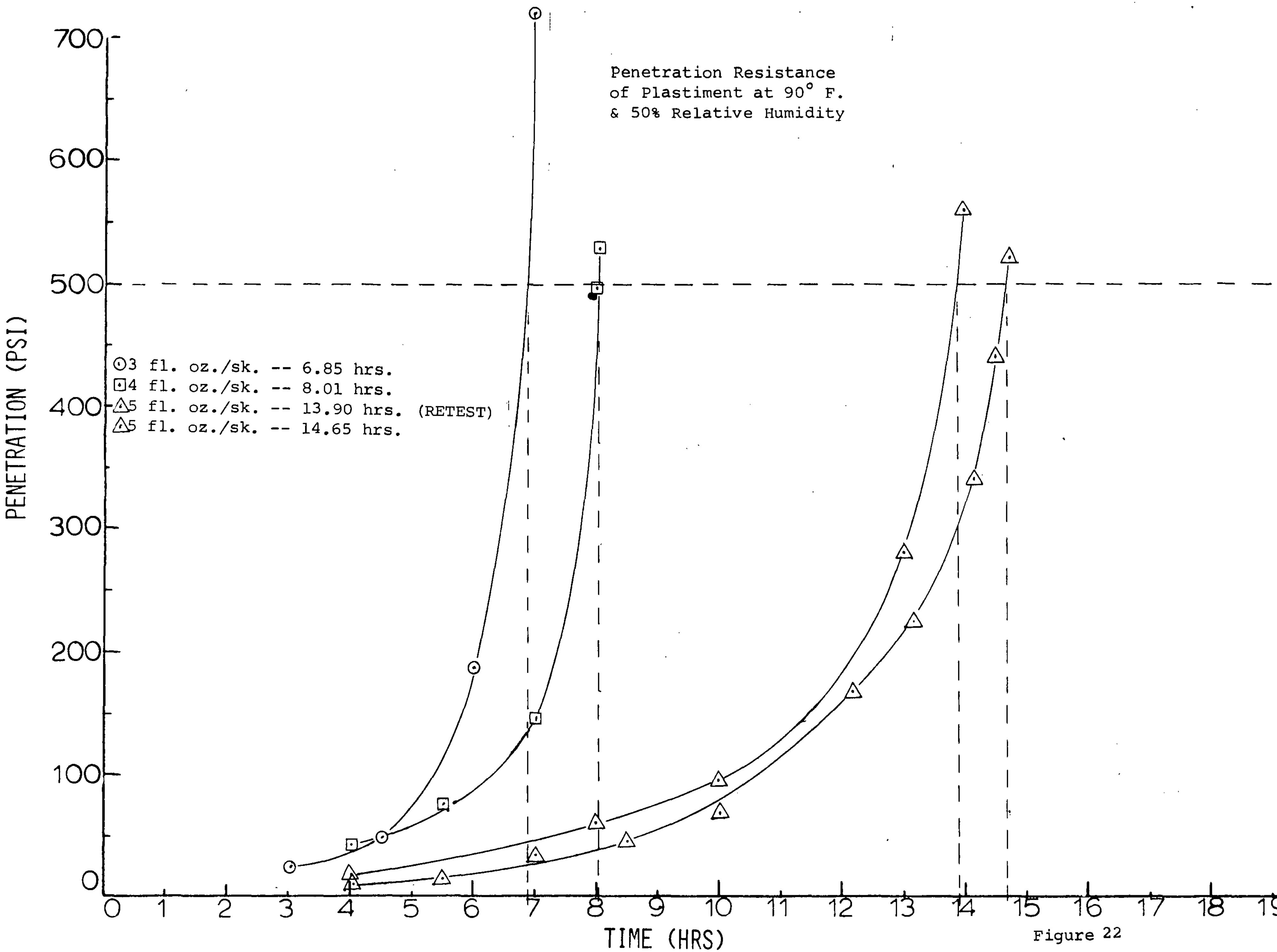


Figure 20



TIME OF INITIAL SET
Penetration Resistance
of Plastiment at 80° F.
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
○ 3 fl. oz./sk. -- 7.37 hrs.
□ 4 fl. oz./sk. -- 9.32 hrs.
△ 5 fl. oz./sk. -- 10.40 hrs.
2
3
4
5
6
7
8
9
10
11
TIME (HRS)

Figure 21



Penetration Resistance
of Plastiment at 90° F.
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
3 fl. oz./sk. -- 6.85 hrs.
4 fl. oz./sk. -- 8.01 hrs.
5 fl. oz./sk. -- 13.90 hrs. (RETEST)
5 fl. oz./sk. -- 14.65 hrs.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
TIME (HRS)

Figure 22

TIME OF INITIAL SET

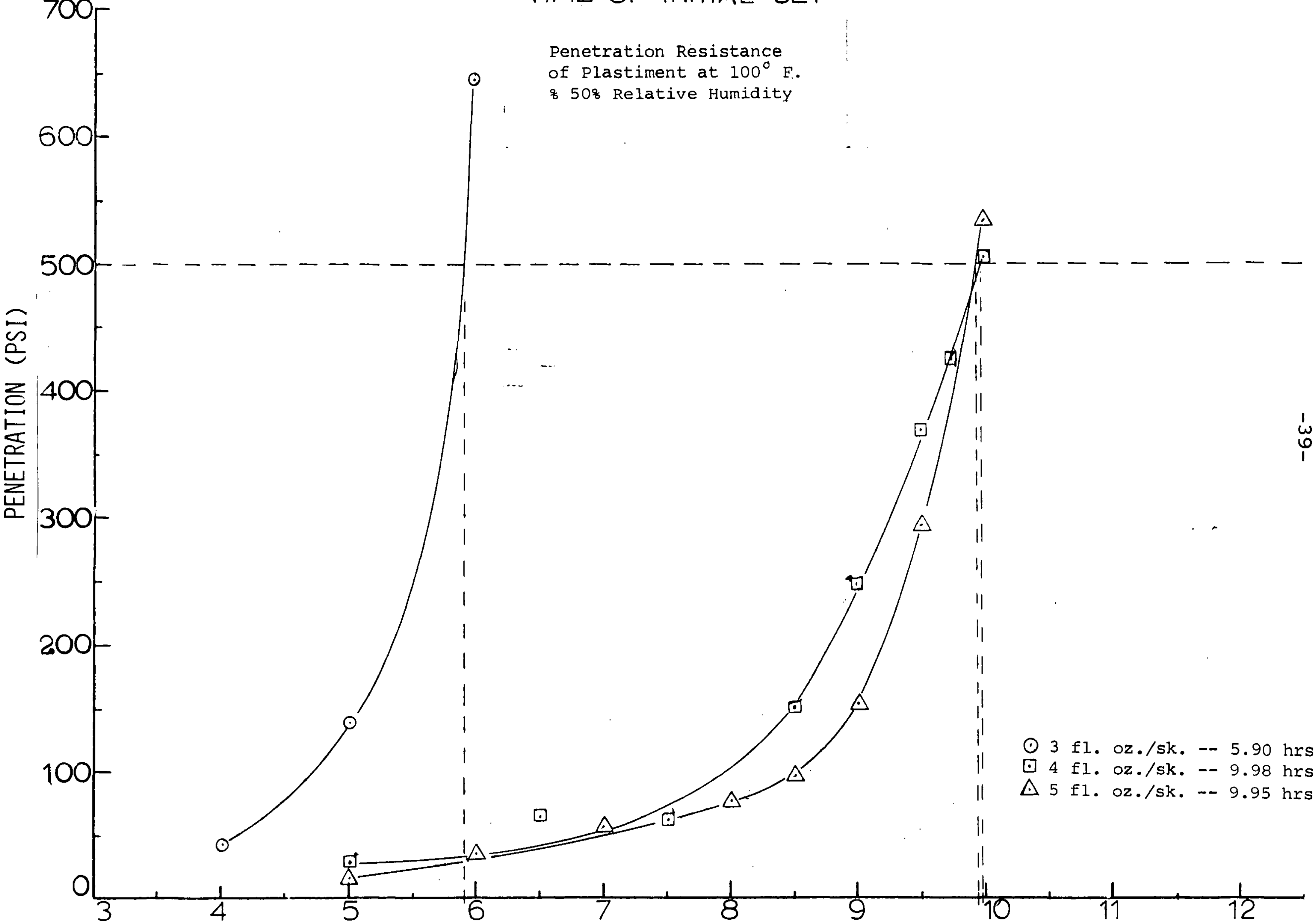
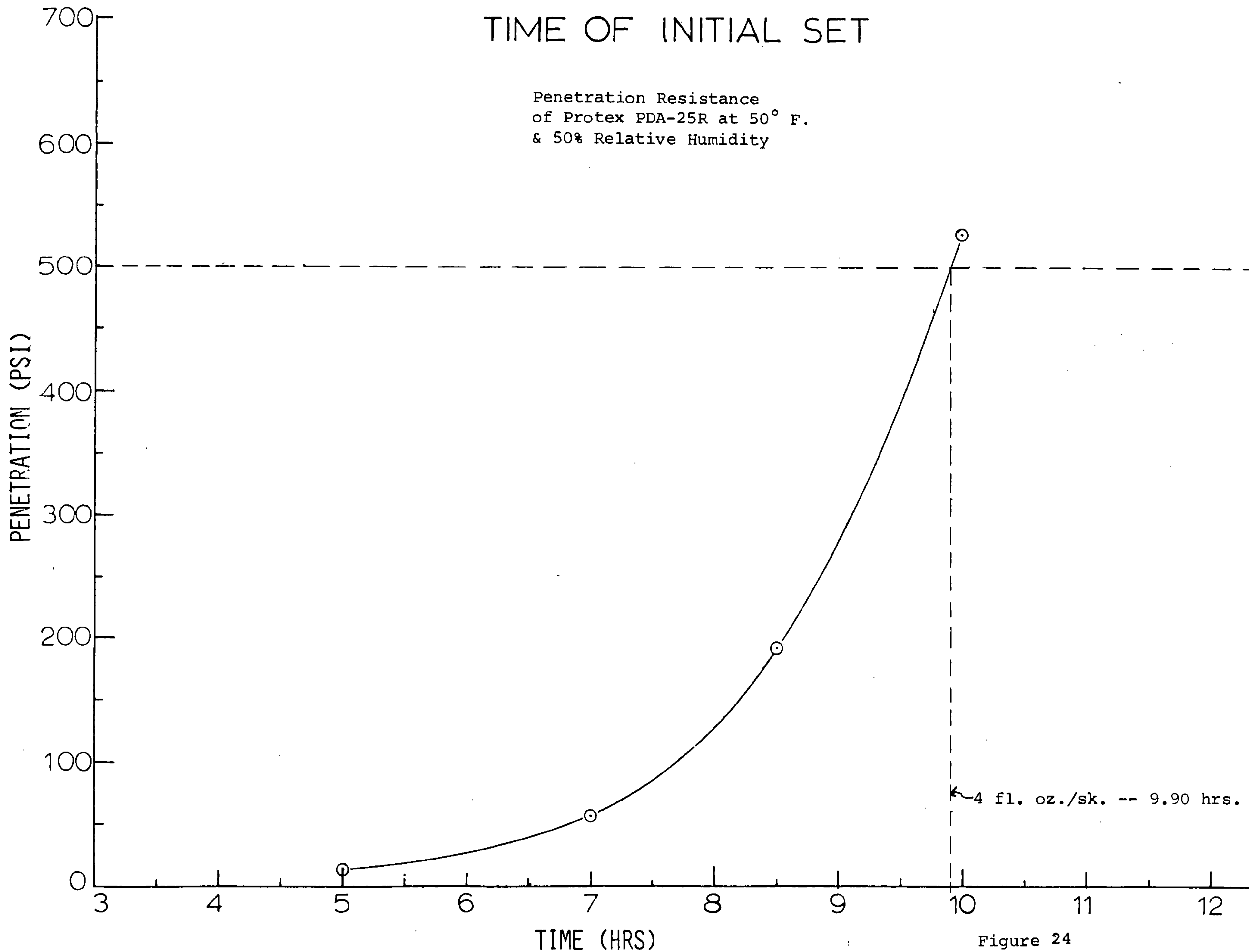


Figure 23



TIME OF INITIAL SET
Penetration Resistance
of Protex PDA-25R at 50° F.
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
3
4
5
6
7
8
9
10
11
12
TIME (HRS)
4 fl. oz./sk. -- 9.90 hrs.

Figure 24

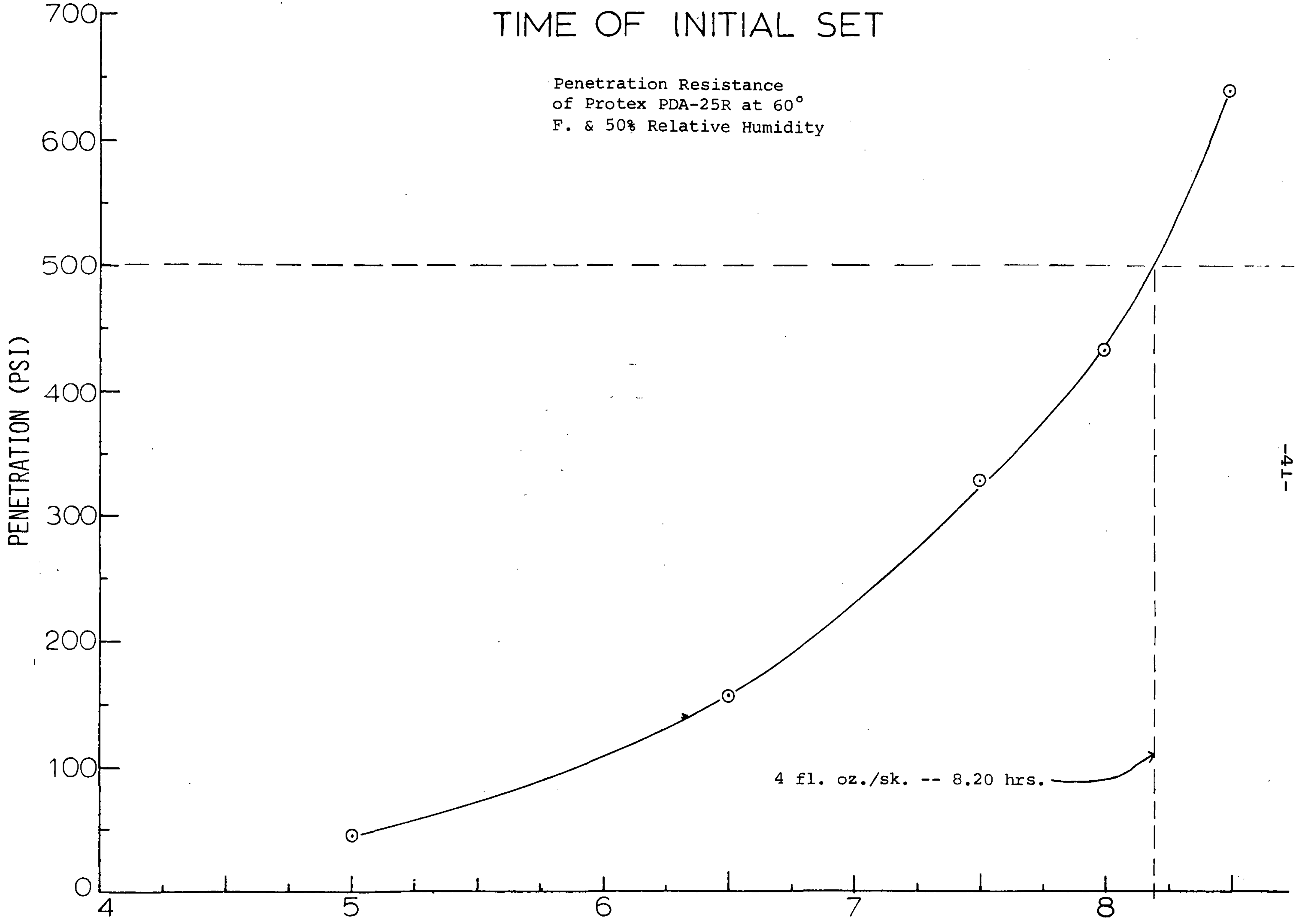

TIME OF INITIAL SET
Penetration Resistance
of Protex PDA-25R at 60°
F. & 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
4
5
6
7
8
TIME (HRS)
4 fl. oz./sk. -- 8.20 hrs.

Figure 25

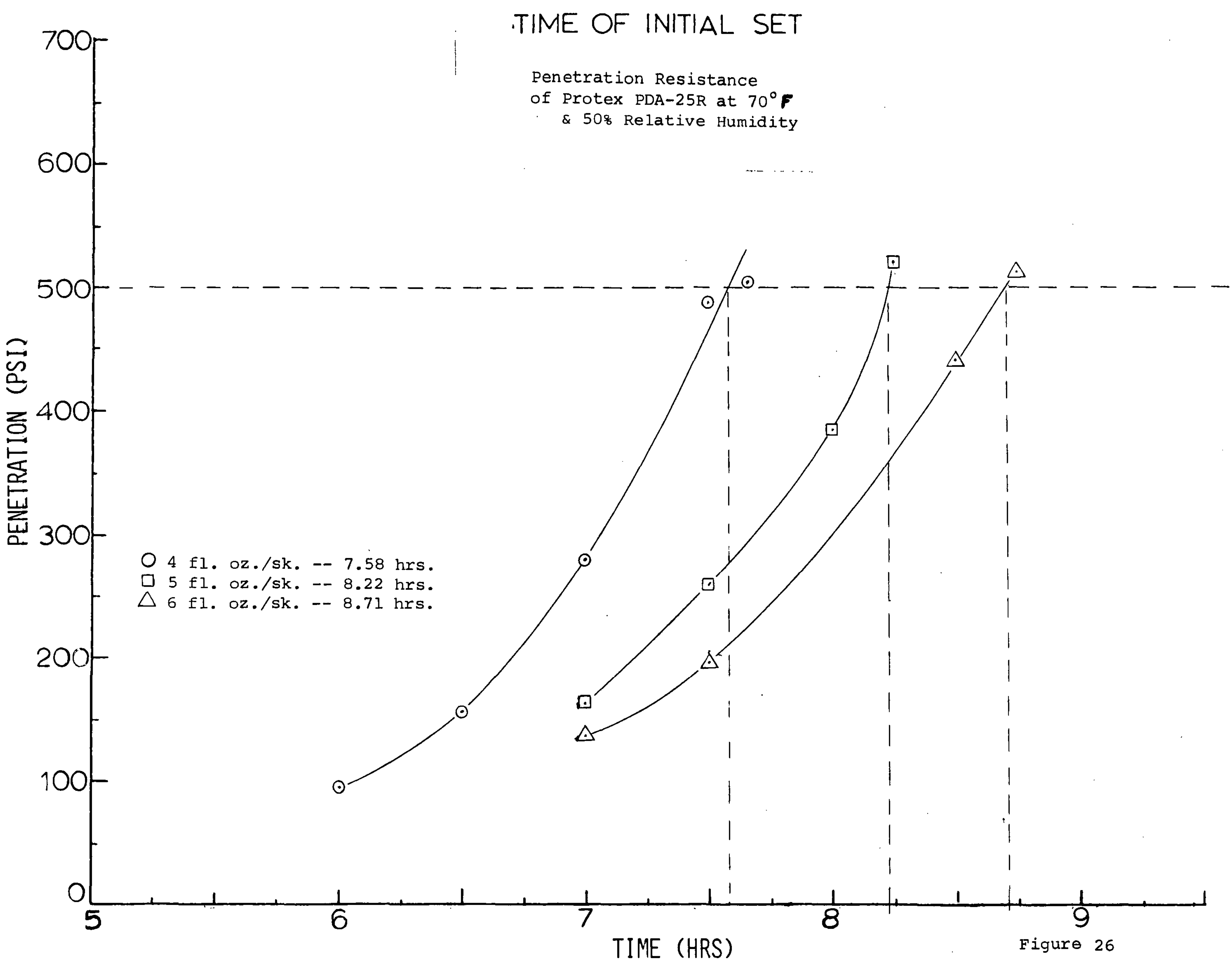

TIME OF INITIAL SET
Penetration Resistance
of Protex PDA-25R at 70°F
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
5
6
7
8
9
TIME (HRS)
○ 4 fl. oz./sk. -- 7.58 hrs.
□ 5 fl. oz./sk. -- 8.22 hrs.
△ 6 fl. oz./sk. -- 8.71 hrs.

Figure 26

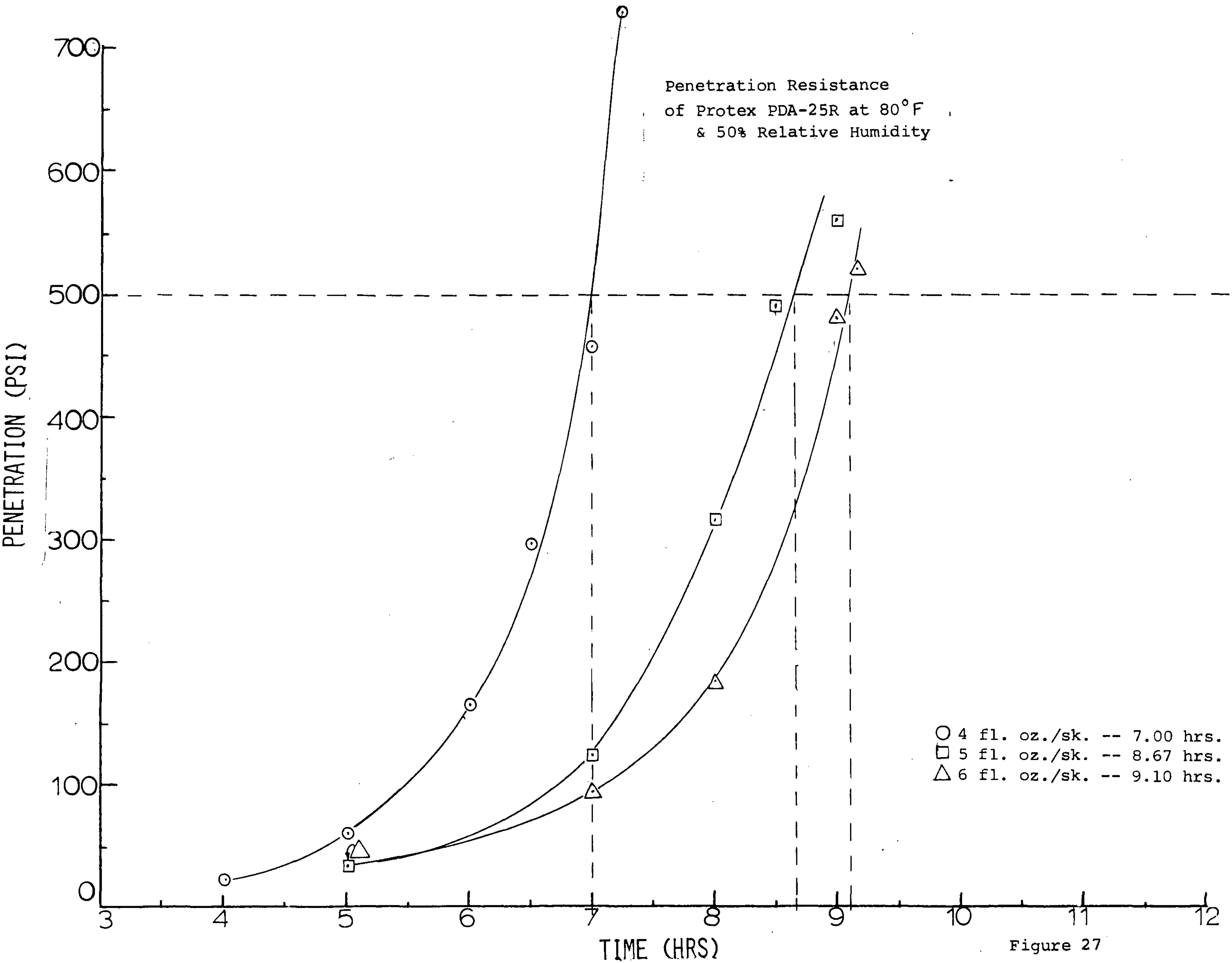
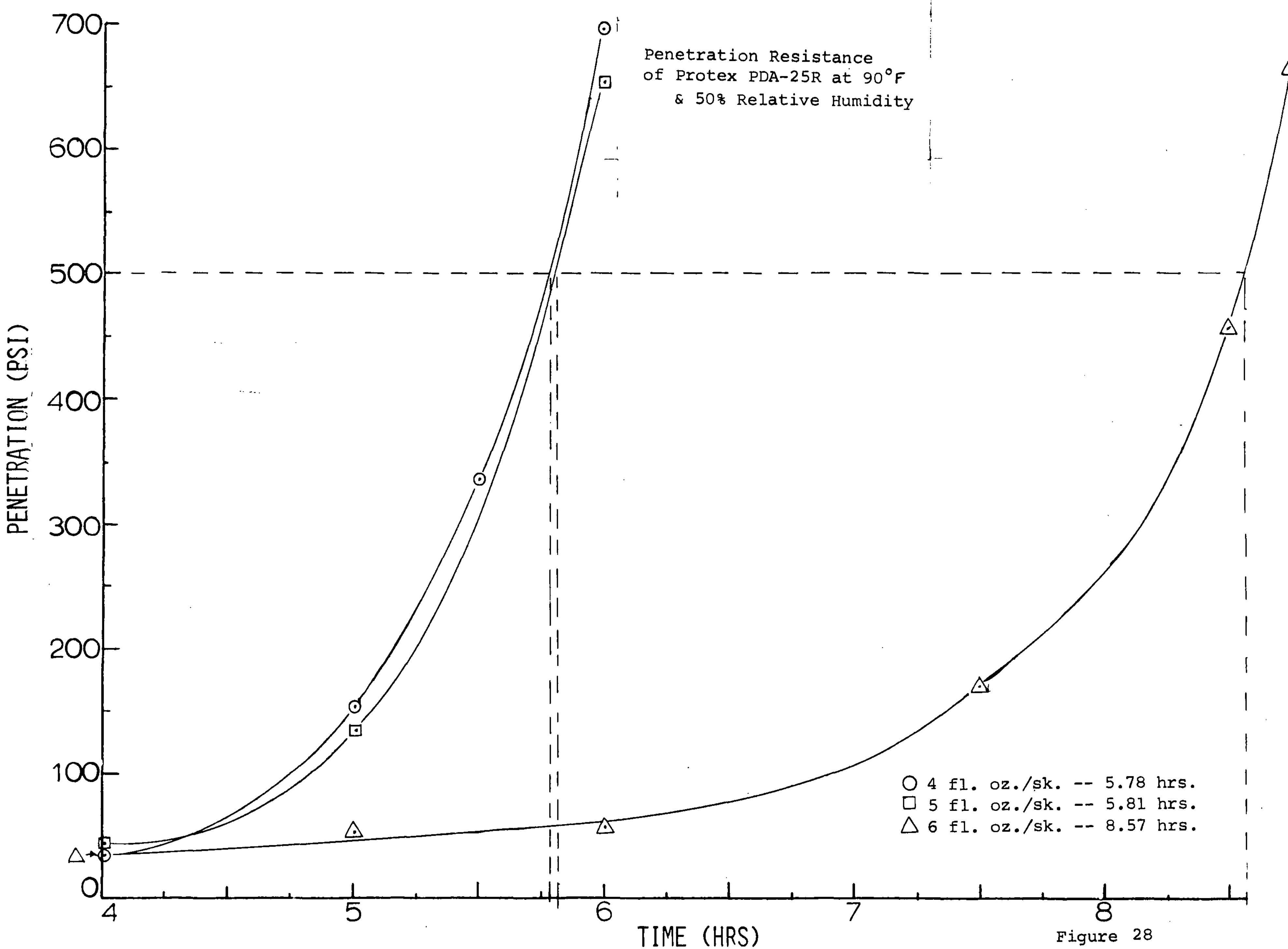

Penetration Resistance
of Protex PDA-25R at 80°F
& 50% Relative Humidity
PENETRATION (PSI)
TIME (HRS)
0
100
200
300
400
500
600
700
3
4
5
6
7
8
9
10
11
12
○ 4 fl. oz./sk. -- 7.00 hrs.
□ 5 fl. oz./sk. -- 8.67 hrs.
△ 6 fl. oz./sk. -- 9.10 hrs.

Figure 27



Penetration Resistance
of Protex PDA-25R at 90°F
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
4
5
6
7
8
TIME (HRS)
○ 4 fl. oz./sk. -- 5.78 hrs.
□ 5 fl. oz./sk. -- 5.81 hrs.
△ 6 fl. oz./sk. -- 8.57 hrs.

Figure 28

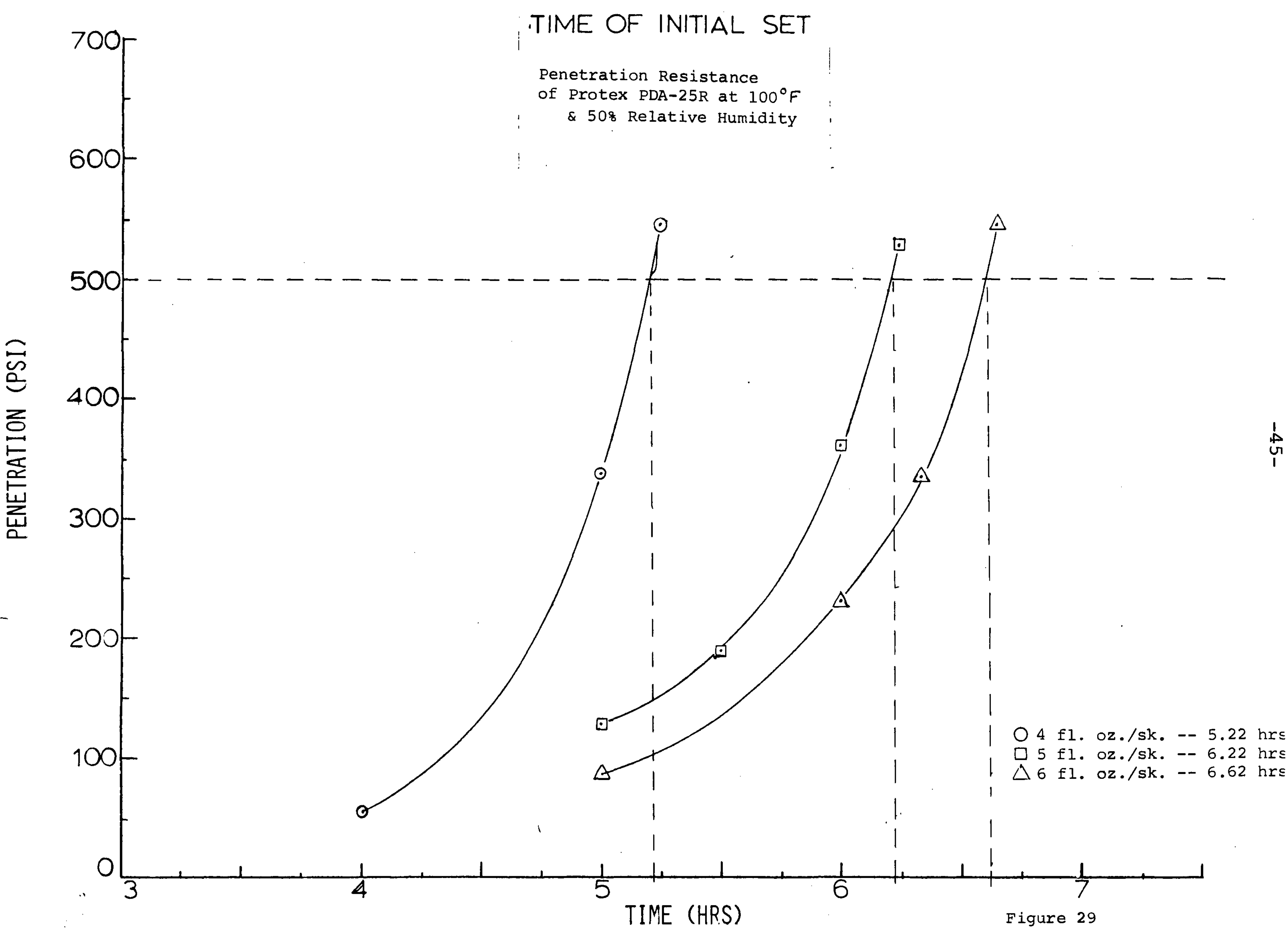
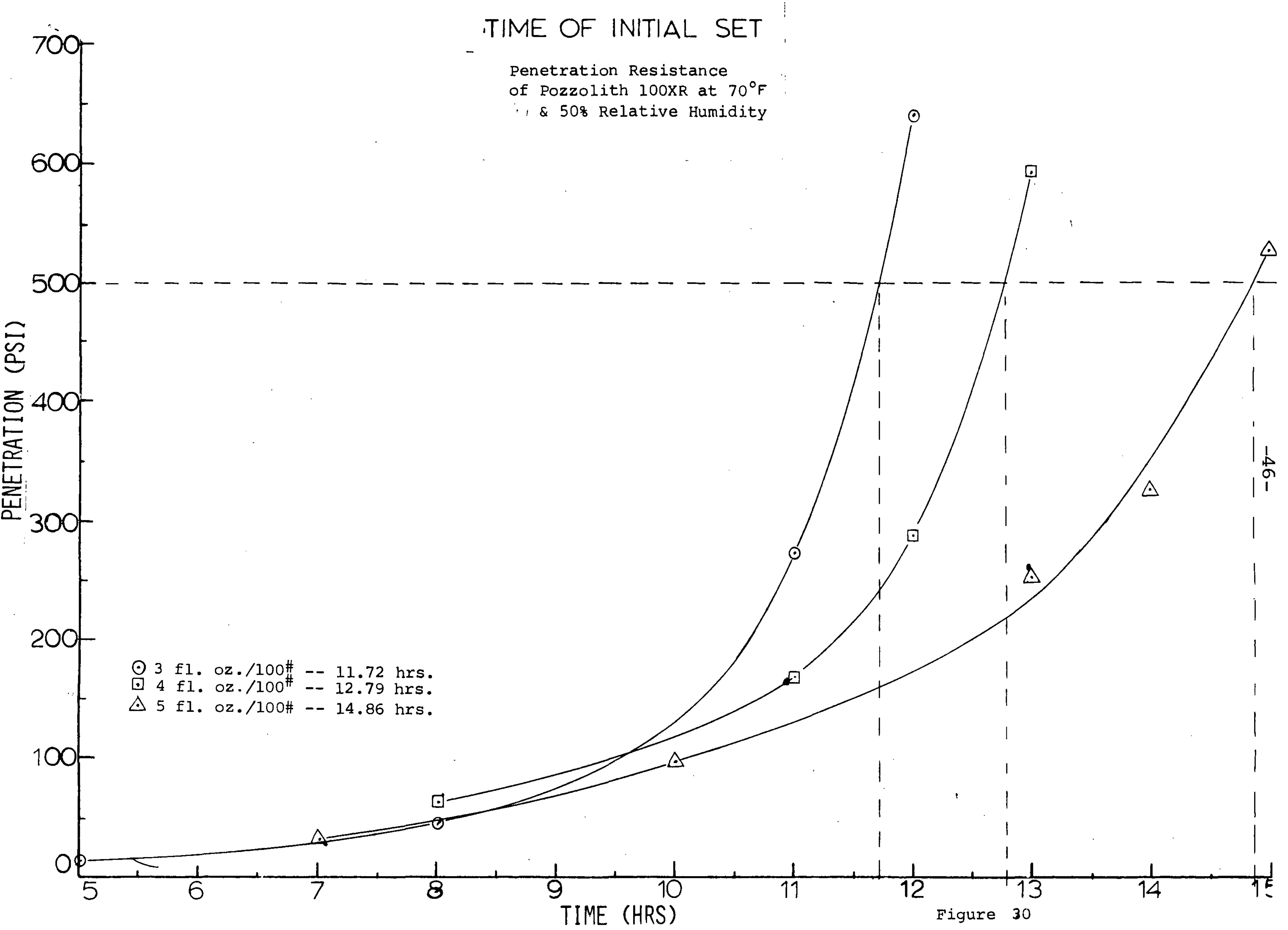

TIME OF INITIAL SET
Penetration Resistance
of Protex PDA-25R at 100°F
& 50% Relative Humidity
700
600
500
400
300
200
100
0
PENETRATION (PSI)
3
4
5
6
7
TIME (HRS)
○ 4 fl. oz./sk. -- 5.22 hrs
□ 5 fl. oz./sk. -- 6.22 hrs
△ 6 fl. oz./sk. -- 6.62 hrs

Figure 29



TIME OF INITIAL SET
Penetration Resistance
of Pozzolith 100XR at 70°F
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
5
6
7
8
9
10
11
12
13
14
15
TIME (HRS)
3 fl. oz./100# -- 11.72 hrs.
4 fl. oz./100# -- 12.79 hrs.
5 fl. oz./100# -- 14.86 hrs.

Figure 30

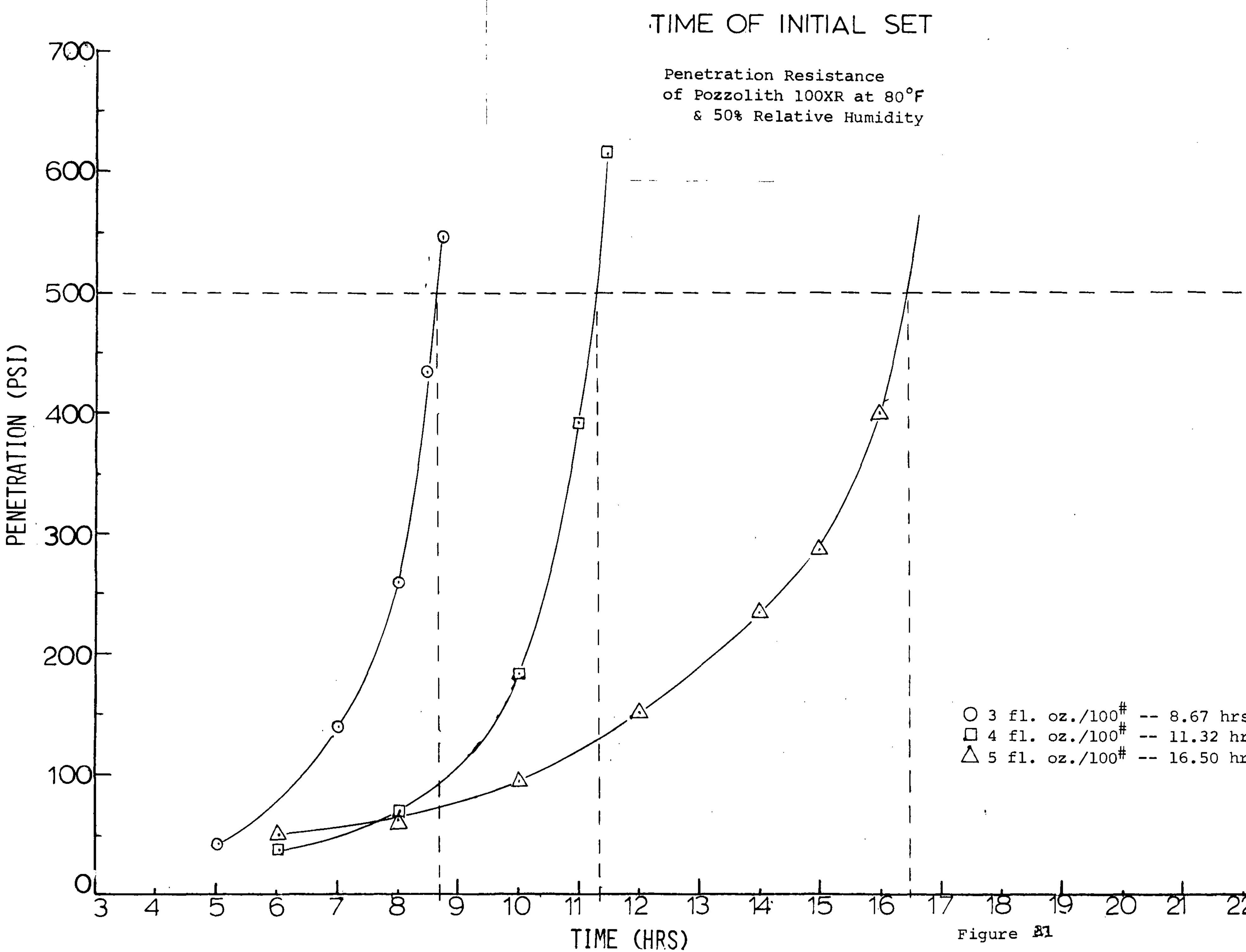

TIME OF INITIAL SET
Penetration Resistance
of Pozzolith 100XR at 80°F
& 50% Relative Humidity
700
600
500
400
300
200
100
0
PENETRATION (PSI)
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
TIME (HRS)
○ 3 fl. oz./100# -- 8.67 hrs.
□ 4 fl. oz./100# -- 11.32 hrs.
△ 5 fl. oz./100# -- 16.50 hrs.

Figure 21

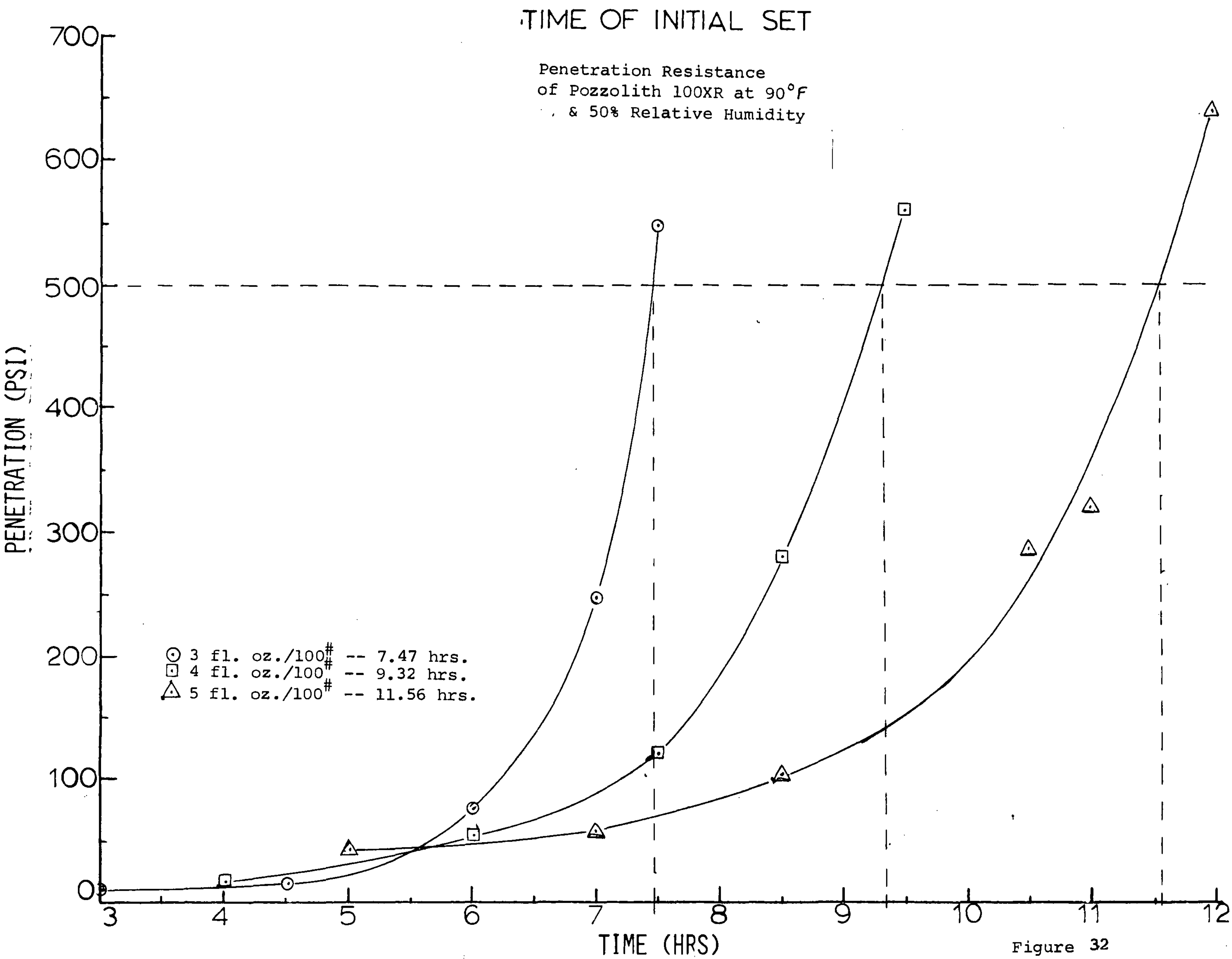

TIME OF INITIAL SET
Penetration Resistance
of Pozzolith 100XR at 90°F
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
3 fl. oz./100# -- 7.47 hrs.
4 fl. oz./100# -- 9.32 hrs.
5 fl. oz./100# -- 11.56 hrs.
3
4
5
6
7
8
9
10
11
12
TIME (HRS)

Figure 32

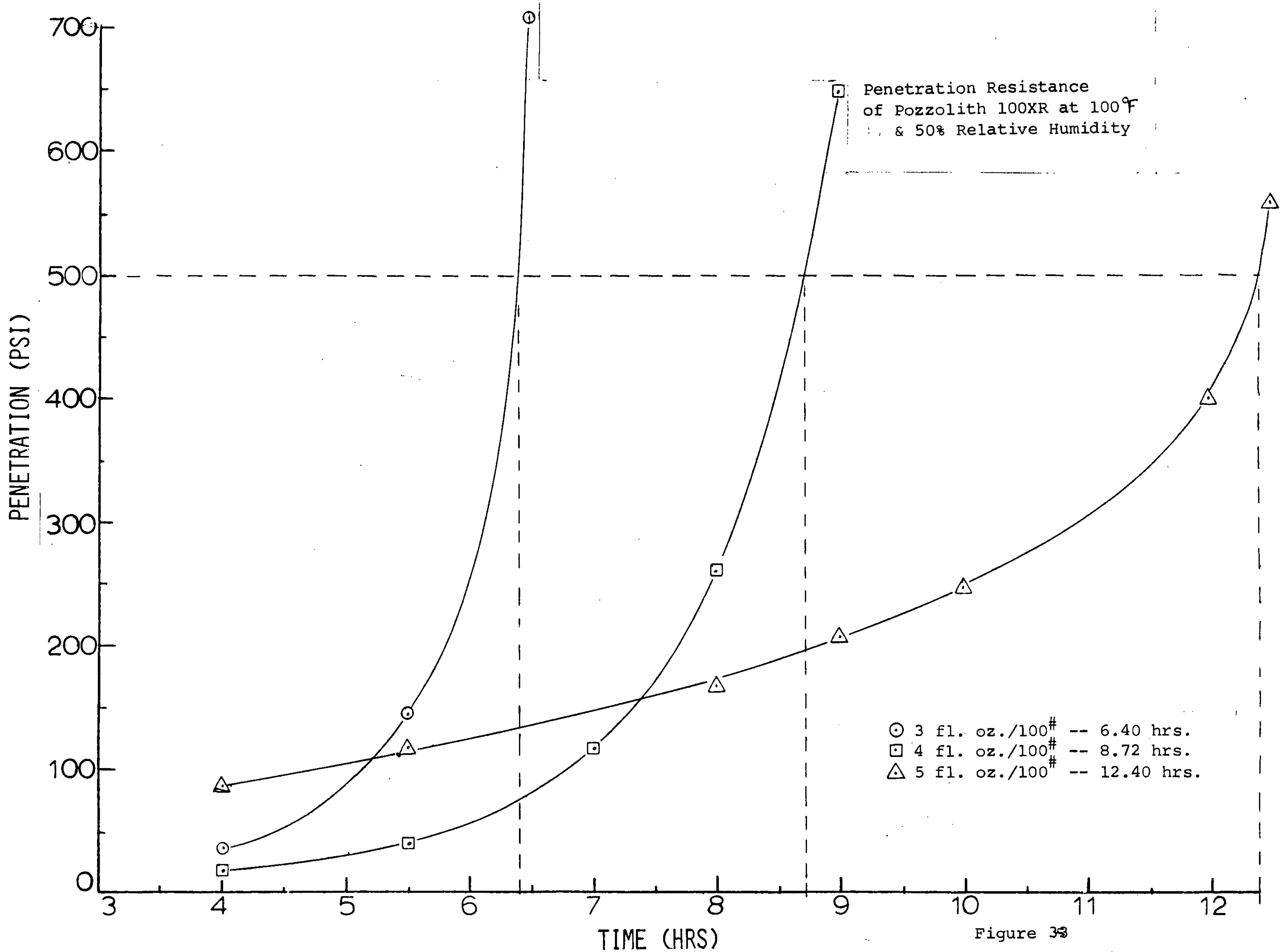

Penetration Resistance
of Pozzolith 100XR at 100°F
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
3
4
5
6
7
8
9
10
11
12
TIME (HRS)
⊙ 3 fl. oz./100# -- 6.40 hrs.
⊡ 4 fl. oz./100# -- 8.72 hrs.
△ 5 fl. oz./100# -- 12.40 hrs.

Figure 38

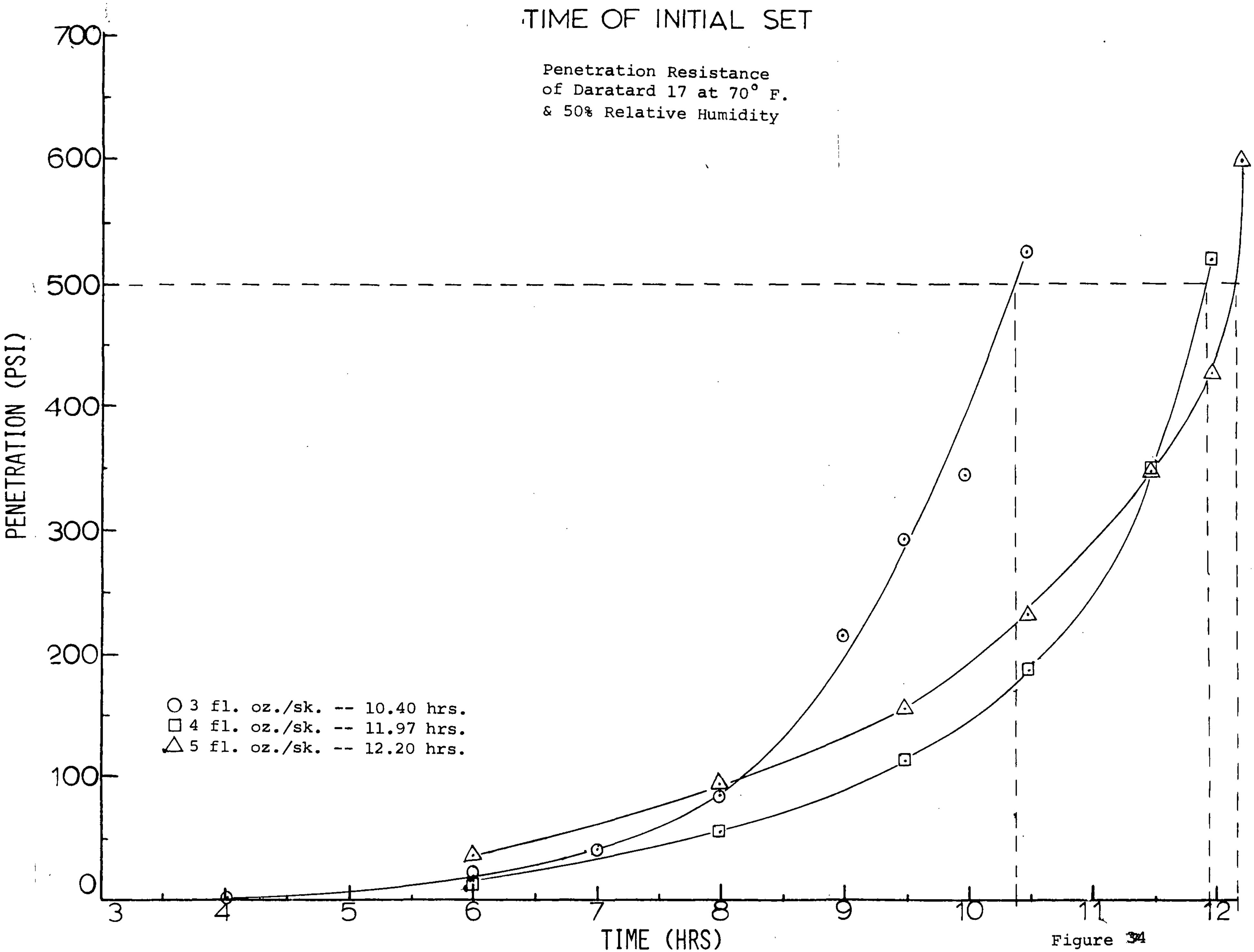

TIME OF INITIAL SET
Penetration Resistance
of Daratard 17 at 70° F.
& 50% Relative Humidity
PENETRATION (PSI)
0
100
200
300
400
500
600
700
TIME (HRS)
3
4
5
6
7
8
9
10
11
12
○ 3 fl. oz./sk. -- 10.40 hrs.
□ 4 fl. oz./sk. -- 11.97 hrs.
△ 5 fl. oz./sk. -- 12.20 hrs.

Figure 34

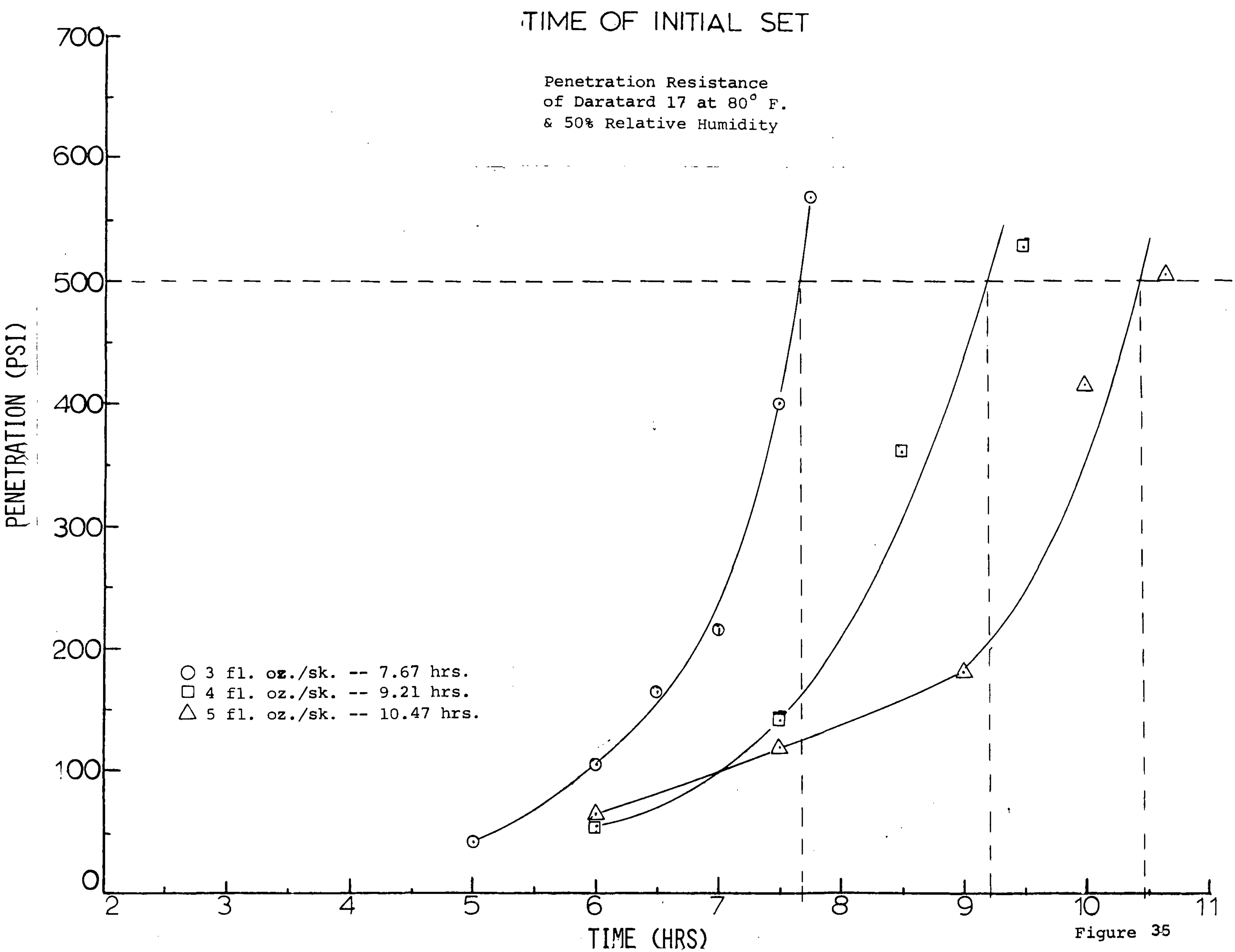

TIME OF INITIAL SET
Penetration Resistance
of Daratard 17 at 80° F.
& 50% Relative Humidity
700
600
500
400
300
200
100
0
PENETRATION (PSI)
○ 3 fl. oz./sk. -- 7.67 hrs.
□ 4 fl. oz./sk. -- 9.21 hrs.
△ 5 fl. oz./sk. -- 10.47 hrs.
2
3
4
5
6
7
8
9
10
11
TIME (HRS)

Figure 35

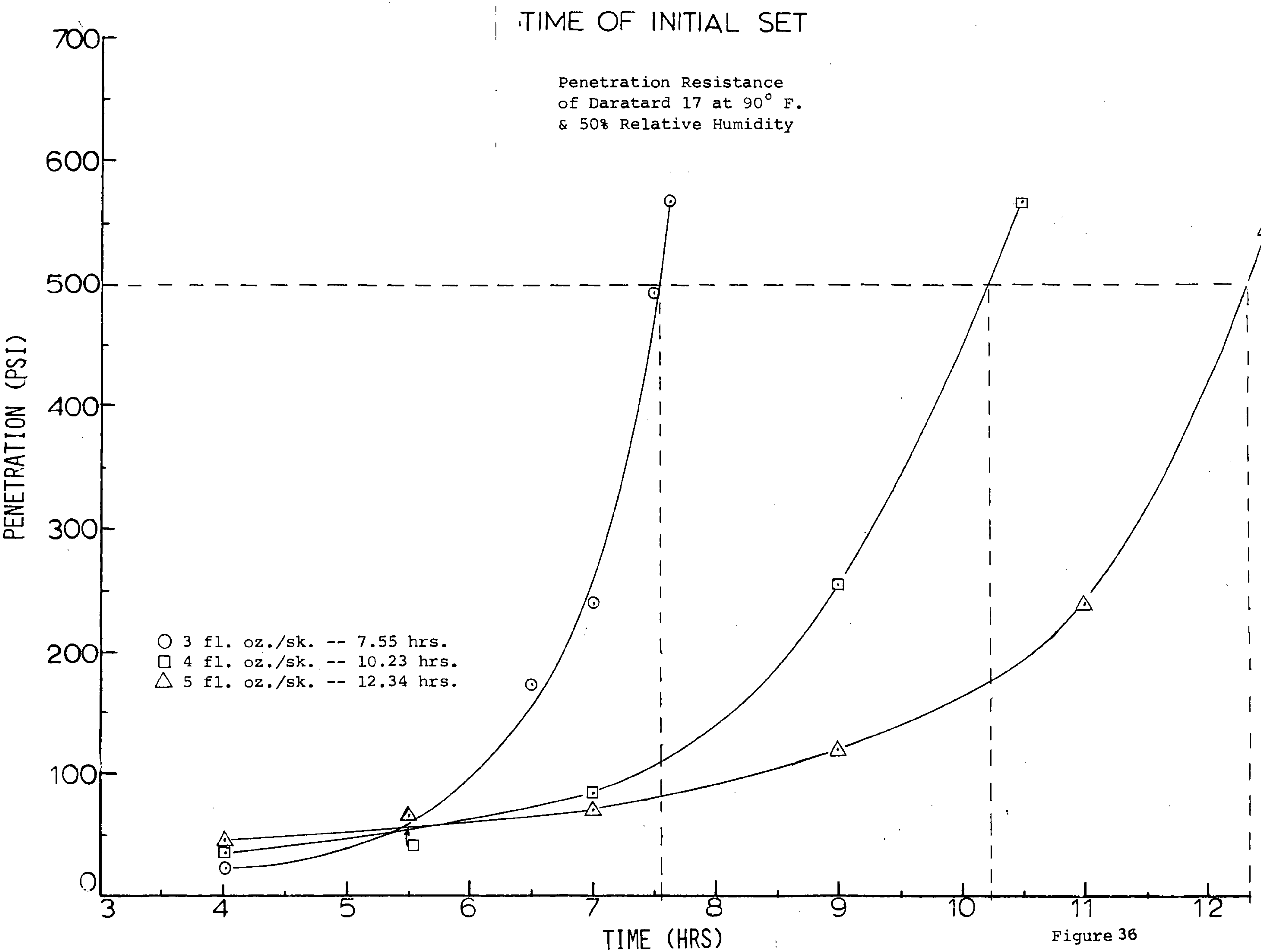

TIME OF INITIAL SET
Penetration Resistance
of Daratard 17 at 90° F.
& 50% Relative Humidity
○ 3 fl. oz./sk. -- 7.55 hrs.
□ 4 fl. oz./sk. -- 10.23 hrs.
△ 5 fl. oz./sk. -- 12.34 hrs.
PENETRATION (PSI)
TIME (HRS)
700
600
500
400
300
200
100
0
3
4
5
6
7
8
9
10
11
12

Figure 36

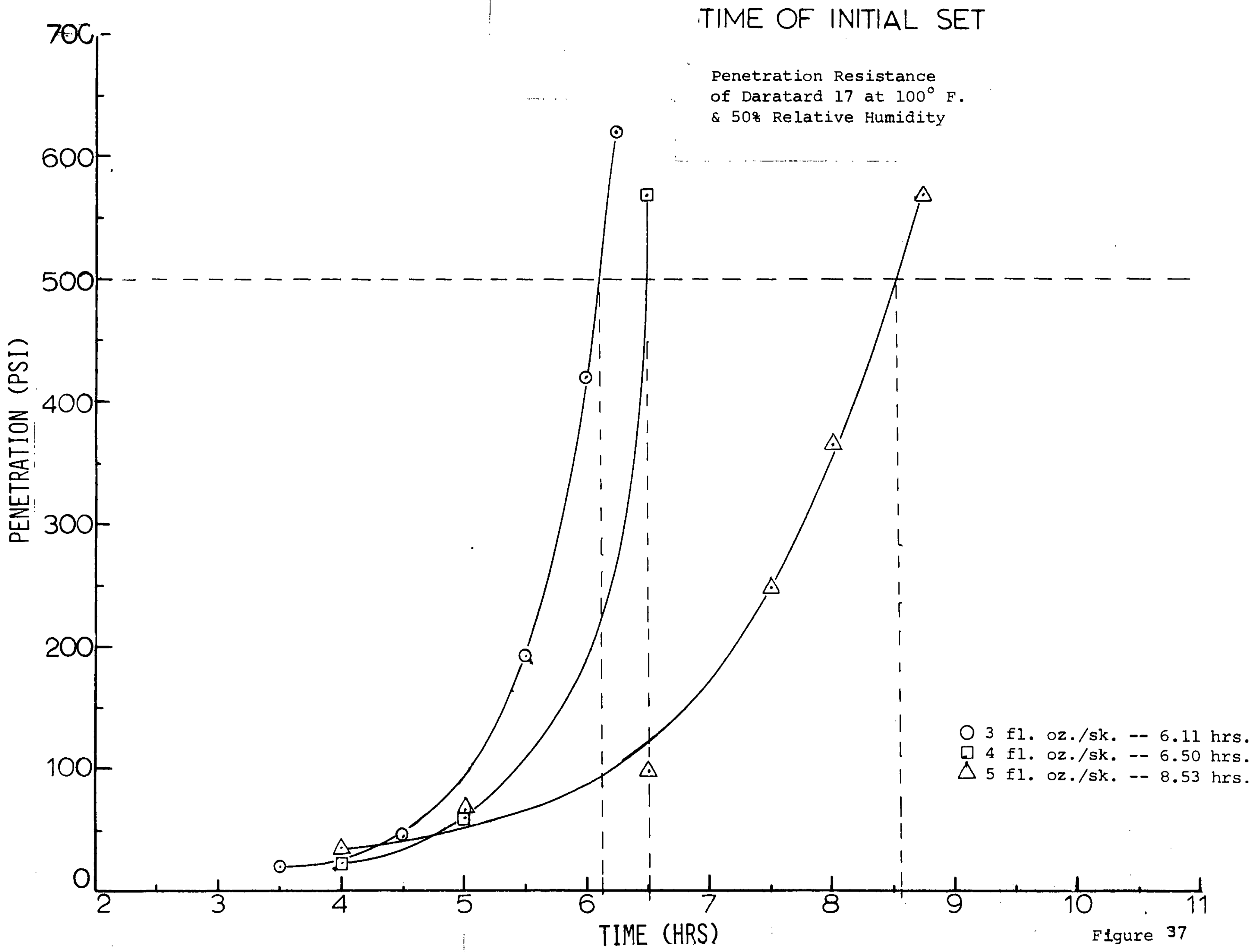

TIME OF INITIAL SET
Penetration Resistance
of Daratard 17 at 100° F.
& 50% Relative Humidity
PENETRATION (PSI)
700
600
500
400
300
200
100
0
2
3
4
5
6
7
8
9
10
11
TIME (HRS)
3 fl. oz./sk. -- 6.11 hrs.
4 fl. oz./sk. -- 6.50 hrs.
5 fl. oz./sk. -- 8.53 hrs.

Figure 37