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The effects of caffein on dark adaptation

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Abstract

Caffein ingestion increases scotopic sensitivity during dark adaptation. The influence is seen with both large (2°26') and small (11.5') test stimuli. This indicates that the caffein effect is not due to changes in spatial summation. Since the effect peaks about 20 minutes after onset of dark adaptation, there may be a greater effect on the kinetics of dark adaptation than on the overall sensitivity of the visual system.

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THE EFFECTS OF CAFFEIN ON DARK ADAPTATION

A Thesis

Presented to

The Faculty and Students

Pacific University College of Optometry

In Partial Fulfillment

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Doctor of Optometry

By

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Richard W. Davis

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ABSTRACT

Caffein ingestion increases scotopic sensitivity during dark adaptation. The influence is seen with both large ($2^{o}26'$) and small (11.5') test stimuli. This indicates that the caffein effect is not due to changes in spatial summation. Since the effect peaks about 20 minutes after onset of dark adaptation, there may be a greater effect on the kinetics of dark adaptation than on the overall sensitivity of the visual system.

INTRODUCTION

Early studies on the effects of caffein on the course and magnitude of dark adaptation indicated that it had little or no effect. However, in 1971, Pitts and Reuvelta reported in separate theses that caffein significantly lowered the dark adaptation threshold. Reuvelta felt that the effect could be explained by increased attention precipitated by the caffein. Pitts disagreed with Reuvelta's theory but could not satisfactorily explain his results.

PURPOSE

The purpose of this study is to determine the effects of caffein on the light detection threshold for a $2^{o}26'$ and an 11.5' stimulus centered 13.5^{o} off fovea during a sixty minute course of dark adaptation. Pitts felt that the effect found by using caffein was still increasing at the end of his testing session (26 minutes). Considering this, we decided to extend the test session to sixty minutes. Two different stimulus sizes were utilized to determine the effect, if any, spatial summation has on the determination of the dark adaptation threshold.

METHOD

I. Subjects:

Six subjects between the ages of twenty to twenty-five years were chosen for the experiment. All were students of Pacific University College of Optometry and were screened for any history of ulcers or heart irregularities before acceptance. Any student wearing a spectacle correction was also eliminated.

All were required to sign a consent form and a general questionnaire (Appendix A) and were given a ten minute explanatory demonstration prior to testing.

II. Apparatus:

The basic dark adaptometer designed by Pitts (Appp E) was used with the following modifications:

1. The fixation stimulus was moved from 9.53° to 13.5° off fovea to insure the smallest concentration of cones as possible within the physical limitations of the apparatus.
2. Because we were most concerned with the rod adaptation levels, the wavelength of the test source was reduced to 490 nm (half-amplitude band width of 19.2 nm).
3. Two test sizes were used and constructed as to be easily interchanged. The larger

stimulus size subtended a visual angle of $2^{\circ}26'$ and the smaller stimulus of 11.5'.

4. A double thickness plate-glass beam splitter was installed to allow establishment of a baseline threshold while the pre-adapting stimulus was on.

5. The two millimeter artifical pupil was removed from the apparatus and installed in a trial frame to be worn by the subject. This was done as the increased stimulus to fixation distance was of such magnitude that precise fixation and alignment became extremely critical. (It should noted at this point that the experimenters did not employ a mydriatic as it was felt that under no circumstances would the pupillary fluctuations be so great that the pupil size would be less than that of the artificial pupil.)

III. Procedure:

Seventy-two gelatin capsules filled with 125mg. caffein and 125mg. citric acid ("Test"-T), fourty - eight capsules filled with 125mg. citric acid, 125mg. lactose, and 50mg. magnesium carbonate ("Placebo"-P), and twenty-four empty capsules ("Control"-C) were prepared. The capsules were subdivided into six groups

of four capsules for each subject in the following manner: three packets of four capsules each-caffein, two packets of four capsules each-placebo,and one packet of four empty capsules. The packets of capsules for each subject were ordered and numbered in random sequence. A third party assigned one group of packets to each subject and retained the list of the assignments throughout the testing sessions so as to insure a double blind experiment.

Each subject was instructed to take one capsule each half-hour beginning two hours prior to the start of each testing session, the rationale being that the concentration of caffein in the system would reach a plateau and remain relatively constant during the hour of testing. They were also advised that they need not take the capsules if they were empty. Additional instructions to subjects included: No caffein containing beverages were to be consumed for twenty - four hours prior to each test session, no medications containing Vitamin A were to be taken during the course of all six sessions, and subjects were warned to refrain from informing the testers as to the nature of the capsules taken. No two test sessions were run on any one subject during any twenty-four hour period.

Prior to each test session the subject was required to fill out a daily questionnaire (Appendix B). He

TABLE 1

TEST SEQUENCES

	Sequence	Subject
1.	T T C P T C	D.C.
2.	C C T C T T	G.K.
3.	T C C P T P	J.M.
4.	P T C P T C	C.L.
5.	P T P T C T	D.K.
6.	P T C P T T	D.T.

C -- Control

T -- Caffeine

P -- Placebo

was first dark adapted for a ten minute period and then light adapted to a 299 foot-lambert stimulus centered 13.5° off fovea for ten minutes. At the end of the light adaptation period a one minute threshold was taken using the large stimulus to determine a baseline value for the light adapted state.

NOTE: For all threshold determinations the staircase method of stimulus presentation was used. The test source was set so as to be visible to the subject and its intensity reduced in approximately .2 log-unit steps until the subject reported a negative response and then immediately increased until the first positive response. This procedure was repeated so as to cross the threshold as many times as possible during each one minute test period.

Threshold values for the large stimulus were determined 4 to 5, 9 to 10, 14 to 15, 19 to 20, 29 to 30, 44 to 45, and 58 to 60 minutes after the onset of dark adaptation. They were also determined 5 to 6, 10 to 11, 15 to 16, 20 to 21, 30 to 31, 45 to 46, and 60 to 62 minutes after the onset of dark adaptation using the small stimulus.

RESULTS

Average values were determined for the ascending and descending limits and threshold defined as the midpoint between the two values (graphical representation of each test session may be found in Appendix C). A T-test was performed on the following pairs of values:

1. Caffein threshold versus non-caffein threshold for each stimulus size at 4-6, 9-11, 14-16, 19-21, 29-31, 44-46, and 58-62 minutes into dark adaptation.
2. Caffein versus non-caffein thresholds for all combined data for each stimulus size.
3. The thresholds for the caffein and non-caffein states of baseline determination.

The mean, standard deviation, and variance was also computed for all the above data. (See computer program.)

In all cases the data pairing was accomplished by compairing first caffein and first non-caffein, second caffein and second non-caffein, and third caffein and third non-caffein test sessions for each subject to minimize the influence of any practice effect on test results. One pair of data (C.L.* 3/4/72-T and 3/2/72-P) were eliminated from the statistical

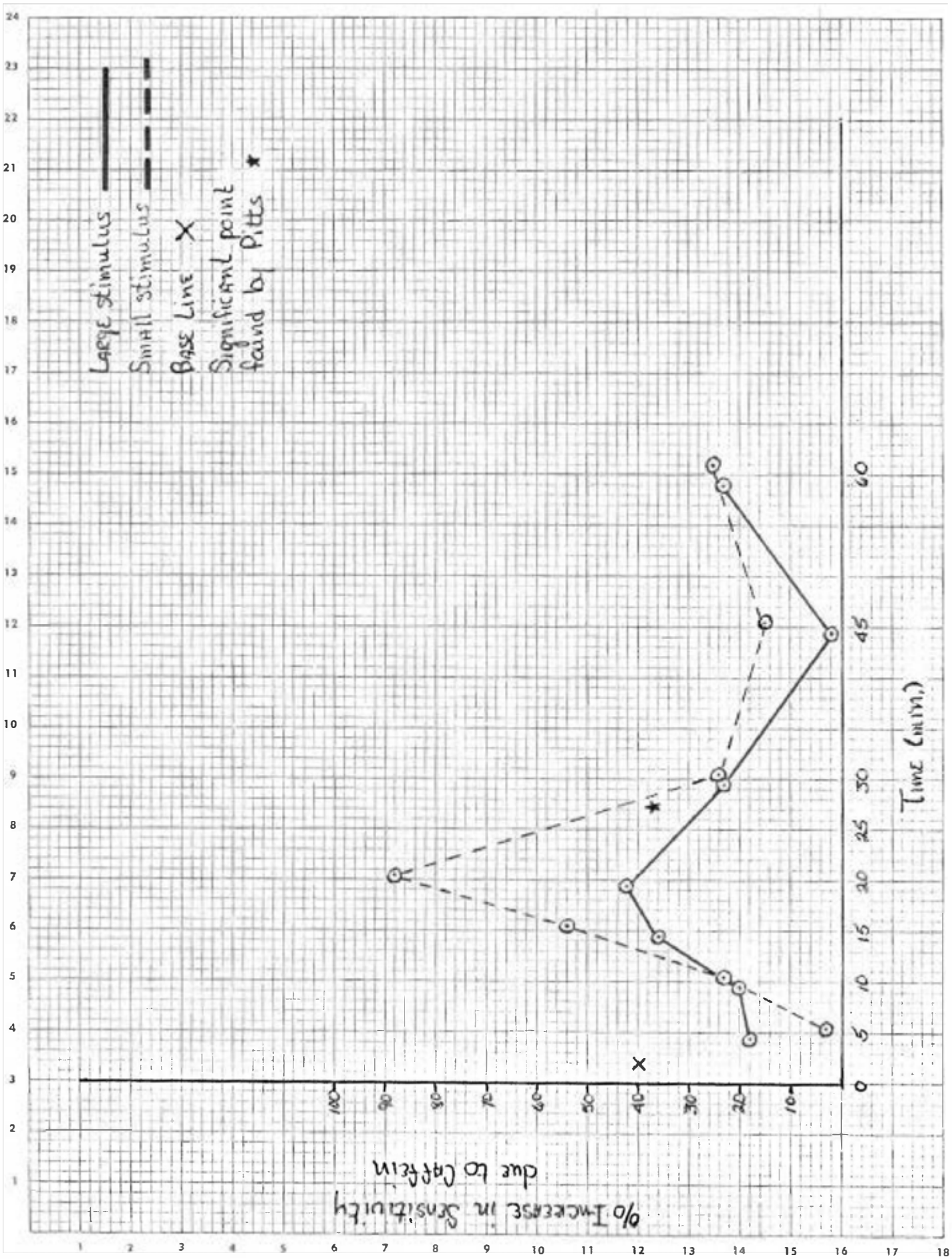
analysis because the average mean values for the data pairs were 2.96 standard deviations from the mean of the rest of the population and could therefore be considered to lie outside the general population. One other point (E.H.* 3/2/72-P and its pair at the 19-21 minute period only) was also eliminated as the authors felt it was erroneous compared to the other data for that session.

Although statistical analysis revealed that the mean threshold difference between caffein and non - caffein tests was significant at the .01 level when all time period data were combined for the large and small stimuli respectively, only certain specific time periods, when analyzed separately, proved to be significant. The large stimulus threshold difference was significant between the .1 and .05 level at 14 to 15 minutes and at the .1 level after 19 to 20 minutes of dark adaptation. The small stimulus threshold values were significant at the .05 level 15 to 16 and at the .1 level 20 to 21 minutes after the onset of dark adaptation. The baseline value difference between caffein and non-caffein trials was also found to be significant between the .1 and .05 level. (See Table 2)

The per-cent increase in sensitivity due to caffein during dark adaptation (Fig. 1) shows an

Stimulus	Time Period	t-value	Two-tailed significance
Large	4-5min.	-0.6973	none
Large	9-10min.	-1.2894	none
Large	14-15min.	-1.7809	.10 T .05
Large	19-20min.	-1.8163	.10
Large	29-30min.	-1.9919	none
Large	44-45min.	-0.1435	none
Large	59-60min.	-1.2991	none
Small	5-6min.	-0.0784	none
Small	10-11min.	-0.0794	none
Small	15-16min.	-2.3040	.05 T
Small	20-21min.	-2.1706	.10 T
Small	30-31min.	-1.0799	none
Small	45-46min.	-0.6769	none
Small	60-62min.	-1.3197	none
All large	0-60min.	-2.8914	.05 T
All small	0-60min.	-3.1369	.05 T
Base line	0min.	-1.8950	.10 T .05

Figure 1


Large stimulus
Small stimulus
Base Line
Significant point found by Pitts
% Increase in Sensitivity due to Caffein
Time (min.)

average overall increase of 25% for the large stimulus and 36% for the small stimulus.

The mean difference between caffein and non - caffein trials was .0965 log units for the large stimulus and .1350 log units for the small stimulus.

CONCLUSION

It is interesting to note that Pitts found a significant difference in threshold values after twenty - seven minutes of dark adaptation. He used a pre-adapting stimulus somewhat brighter than the one used by the authors and because of this the fall off rate of his subject's adaptation curves would be slightly slower than ours. His twenty-seven minute point would therefore correspond to 24 to 25 minutes under our conditions.

The caffein effect peaks 20 minutes into dark adaptation. The effect before and after this is minor although a significant effect is seen in the increment threshold task. It could be hypothesized that instead of reaching a plateau as was hoped, the concentration of caffein peaked in the system at the time periods mentioned and then began to fall off. This hypothesis is further enhanced by the fact that the method of presentation and schedule utilized

for the ingestion of the caffein was the same in both studies and should be checked out in further experiments. On the other hand, caffein does not appear in the urea until one hour after ingestion and persists for up to twenty-four hours. The dosage in this study is spread over a ninety minute period and is thus highly unlikely to show a sharp peak during one ten minute period.

Another explanation of the effect found at 20 minutes is that the rate of dark adaptation under the influence of caffein is greater than if no caffein had been used. If the caffein dark adaptation curve is falling off faster than the non-caffein curve there will exist some point in time where the separation between the two curves is significantly different even though their absolute thresholds are approximately the same.

Previous studies have documented the increased effect caffein has on the metabolic processes in the body. We could therefore assume that chemical reaction rates are consequently increased. The significant difference found in the increment threshold (baseline) would tend to further support this hypothesis.

The fact that there is no real difference between the mean values found for each stimulus size suggests that the ingestion of caffein should have

no effect on visual acuity and that spatial summation does not play a major role in threshold determination during dark adaptation.

Our results show that caffein does have a beneficial effect on dark adaptation. This effect may explain the great intersubject variability found in previous dark adaptation studies and may be a major determinant in the shape of dark adaptation curves. Considering the length and the tedious nature of such studies it is entirely possible that caffein users have, in the past, ingested two or three cups of coffee prior to testing to help them remain awake.

BIBLIOGRAPHY

1. Pitts, W.G. "The Time Course of Dark Adaptation Following Caffein Ingestion" - An unplublished Master's Dissertation Pacific University, Dec. 1971

Computer Program in BASIC Language

for Statistical Analysis

```
LIST
0010 DIM X[100],C$[20]
0020 PRINT "\\TITLE:";
0030 INPUT C$
0040 PRINT
0050 LET N=0
0060 FOR I=1 TO 100
0070   LET N=N+1
0080   PRINT "X=";
0090   INPUT X
0100   IF X=1001 GOTO 0160
0110   PRINT "Y=";
0120   INPUT Y
0130   LET X[I]=(X-Y)
0140   PRINT
0150 NEXT I
0160 LET N=N-1
0170 FOR I=1 TO N
0180   LET J=J+X[I]
0190   LET K=K+X[I]*X[I]
0200 NEXT I
0210 LET L=J*J/N
0220 LET V=(K-L)/(N-1)
0230 LET S=SQR(V)
0240 LET M=J/N
0250 PRINT
0260 PRINT "N=";N;" M=";M;" S=";S;" V=";V;" SS=";(K-L);
0270 PRINT "T=";M/(S/SQR(N))
0280 GOTO 0021
0290 END


END
Ran 12
```

APPENDIX A

Consent Form and General Questionnaire

The purpose of this study is to determine whether or not caffeine has a statistically significant effect upon the dark adaptation curve. In order to accomplish the above, each subject will have his dark adapation curve plotted on six separate occasions.

Two hours prior to five of the test periods, each subject will be required to consume four capsules. Some of these capsules will contain 125mg Caffeine and 125mg Citric Acid, while others will contain 125mg Citric Acid, 125mg. Lactose, and 50mg. Magnesium Carbonate. This caffeine dosage is based on the fact that an average cup of coffee contains between 100 and 150mg. of caffeine.

I understand fully the above and consent to be a subject in this research. I also understand that I may terminate my participation as a subject at any time without advance notice.

_____signature

_____date

1. Name:
2. Age:
3. Sex:
4. Weight:
5. Height:
6. Normal daily consumption of the following beverages:

_____CUPS COFFEE

_____CUPS COCOA

_____CUPS TEA

_____COLA DRINKS

_____BEERS

_____MIXED DRINKS

7. Normal daily tobacco consumption:

_____NONE

_____ONE-HALF PACK

_____ONE PACK

_____OVER ONE PACK

8. Normal hours of sleep per night:

_____HOURS

9. Normal food consumption:

Breakfast	Lunch	Dinner
_____NONE	____NONE	_____NONE
_____LIGHT	____LIGHT	_____LIGHT
_____MEDIUM	____MEDIUM	_____MEDIUM
_____HEAVY	____HEAVY	_____HEAVY

APPENDIX B

Daily Questionnaire
and Instructions to Subjects

NAME:_____

DATE:_____

TIME:_____

QUESTIONNAIRE

Please check the most appropriate for statements listed below.

1. Compared to your normally maintained schedule of rest the amount of rest received in the past twenty-four hours was:

   _____AVERAGE
   _____MORE THAN AVERAGE
   _____LESS THAN AVERAGE

2. Food consumption during the past twelve hours was as follows:

Breakfast	Lunch	Dinner
____NONE	____NONE	____NONE
____LIGHT	____LIGHT	____LIGHT
____MEDIUM	____MEDIUM	____MEDIUM
____HEAVY	____HEAVY	____HEAVY

3. Alcohol consumption during the past twenty-four hours was as follows:

   ____NONE
   ____ONE DRINK
   ____SEVERAL DRINKS
   ____MANY DRINKS

4. Tobacco consumption during the past twenty-four hours was as follows:

____NONE
____ONE-HALF PACK
____ONE PACK
____OVER ONE PACK

5. Medication received in the past twenty-four hours:

6. Physical condition during the past twenty-four hours can best be described as follows:

____GOOD
____SLIGHTLY BELOW PAR
____BAD

7. Emotional state during the past twenty-four hours can best be described as:

____NORMAL
____DEPRESSED
____NERVOUS, FULL OF ANXIETY, HYPER, ETC.

8. Were the instructions given to you by the tester adhered to during the past twelve hours?

____YES
____NO

Instructions pertaining to consumption of capsules prior to testing:

YOUR COMPLETE COOPERATION IS NECESSARY FOR THE SUCCESSFUL COMPLETION OF THIS EXPERIMENT AND WILL BE GREATLY APPRECIATED.

1. You will be given six envelopes each containing four capsules.
2. Two hours prior to each test open the envelope numbered correspondingly to the test session (#1 - first session, #2 - second session, etc.). Take one capsule each half-hour for this two hour period.
3. If the envelope contains empty capsules, you need not take them.
4. DO NOT open the capsules and "taste" the ingredients - some are extremely bitter.
5. Do not comment to the examiners concerning the nature or consistency of the capsules you have taken.

1. No caffeine-containing beverages will be consumed for twenty-four hours prior to the testing period.
2. These beverages contain caffeine and should therefore be totally avoided:

   A. Coffee
   B. Tea
   C. Hot Chocolate and Cocoa
   D. Cola soft drinks

3. No Vitamin A medication will be consumed during the entire duration of the study.
4. Each subject will receive four capsules with a time-table for consumption of the capsules.
5. Each subject will be assigned a time for testing.
6. Answer all questions on the questionnaire given you, as accurately as possible.

APPENDIX C

Graphical Representation of Test Results

LEGEND FOR GRAPHS

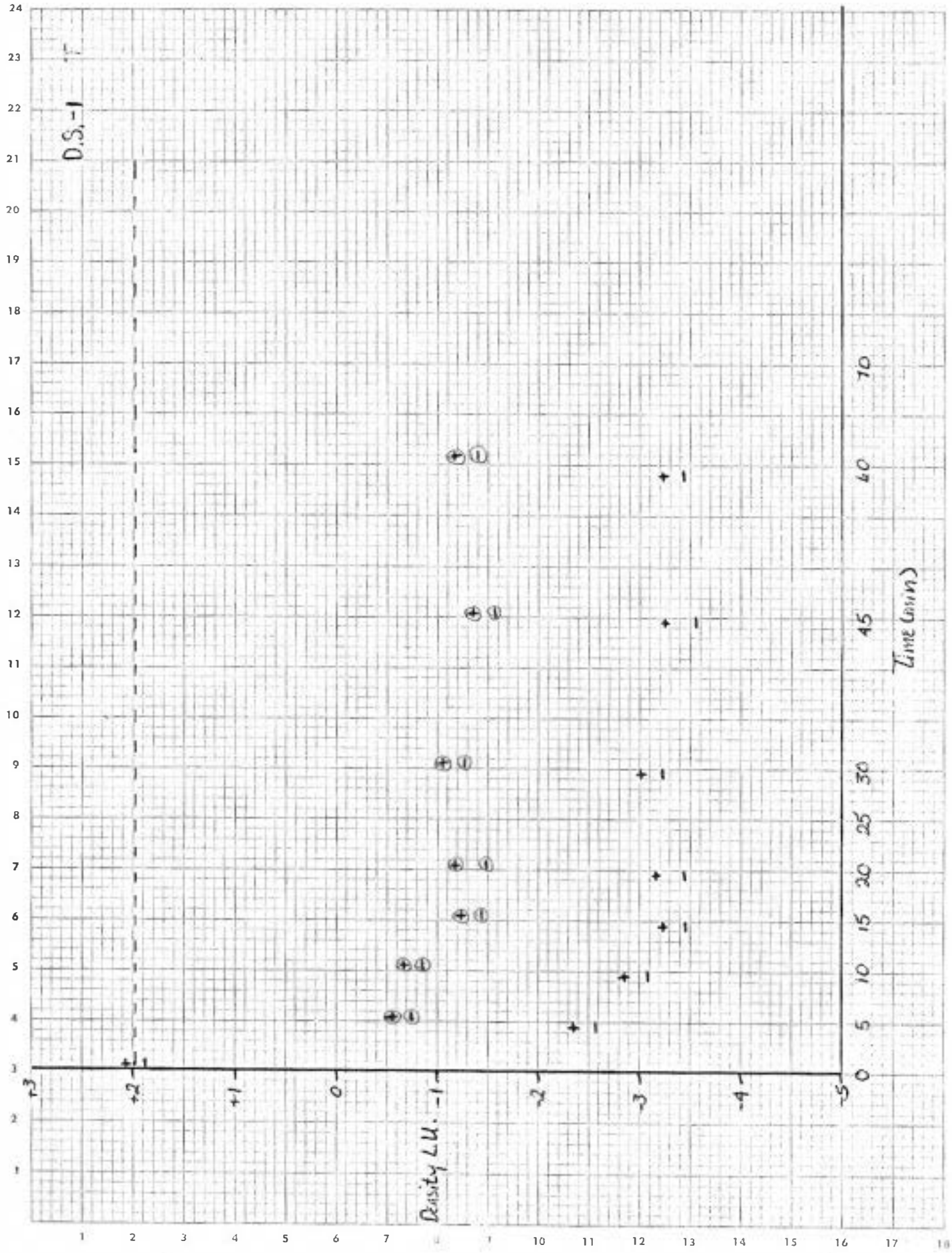
⊕ (red) -- average ascending limit small stimulus

⊖ (red) -- average descending limit small stimulus

\+ (blue) -- average ascending limit large stimulus

\- (blue) -- average descending limit large stimulus

Dotted line -- base line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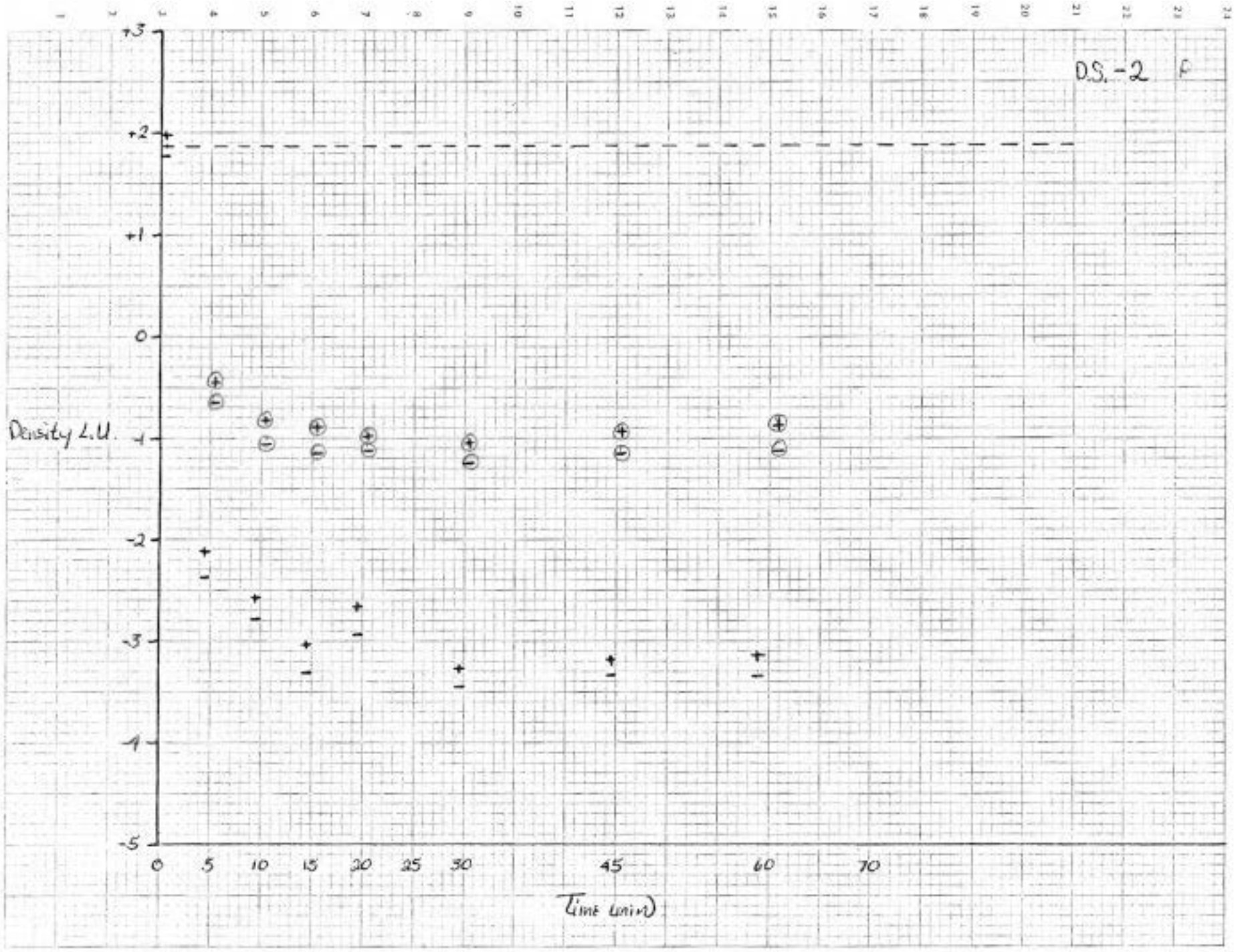
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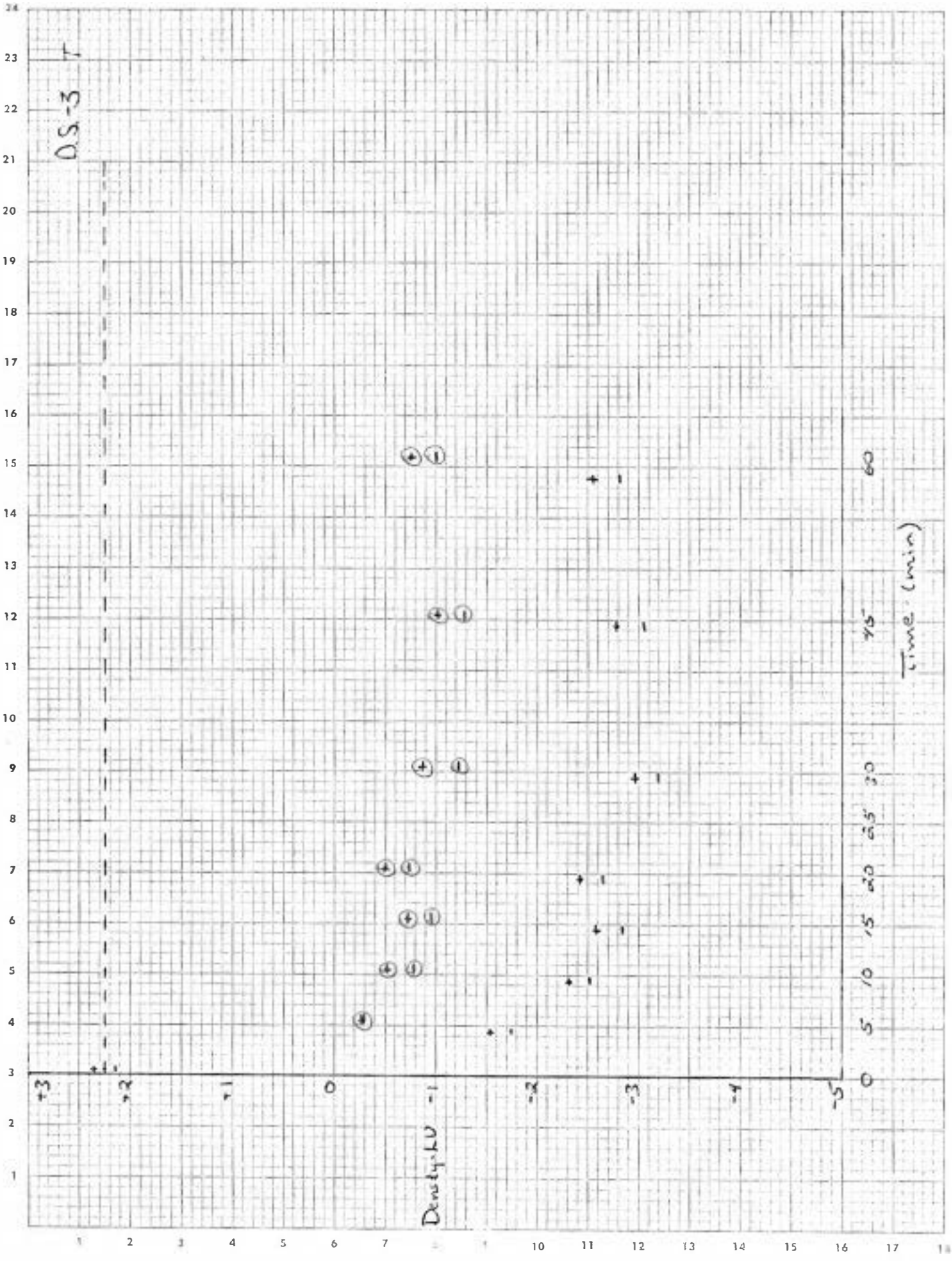
25
30
45
60
70
Time (min)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Density LU
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+2
+1
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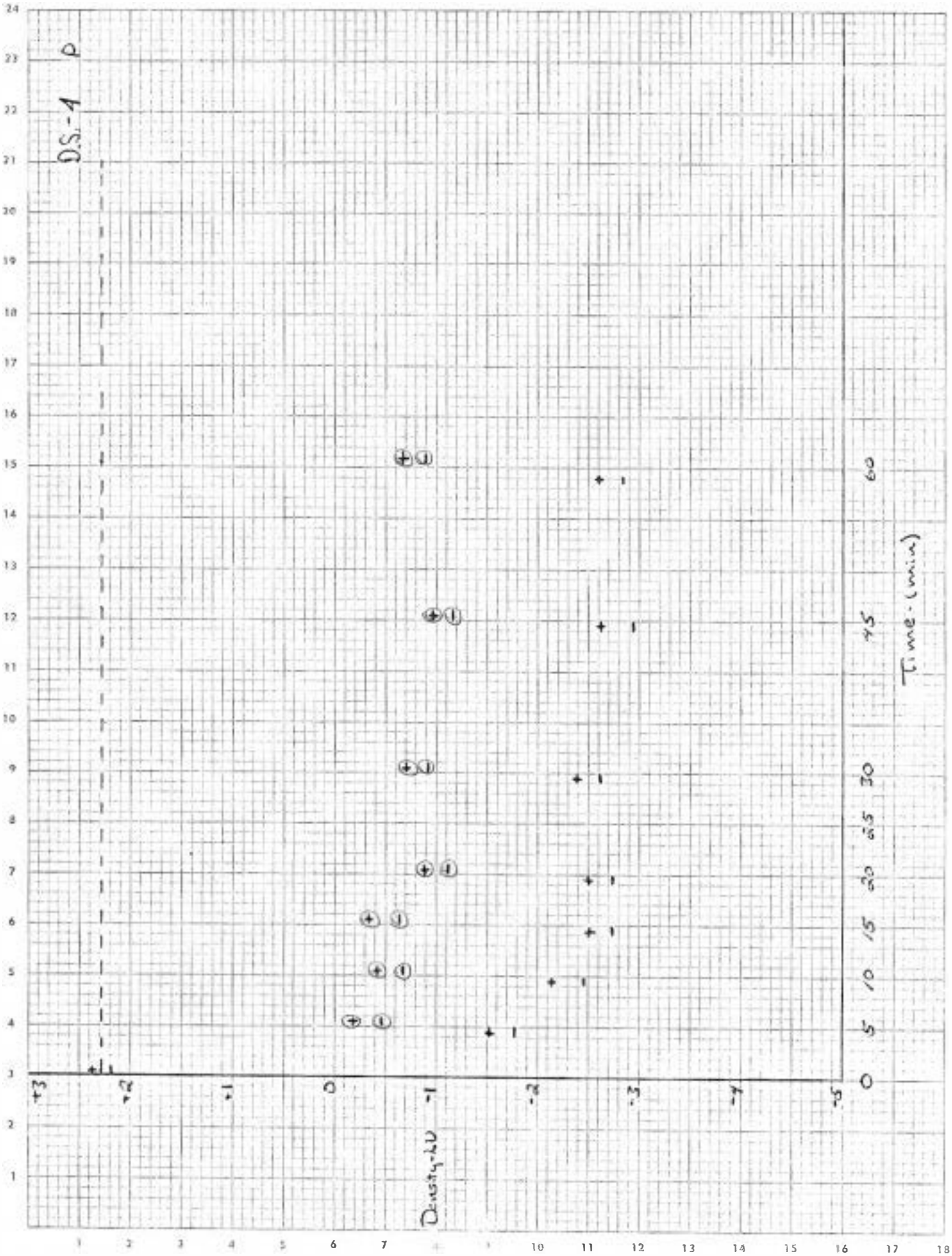
10'
15'
20'
25'
30'
45'
60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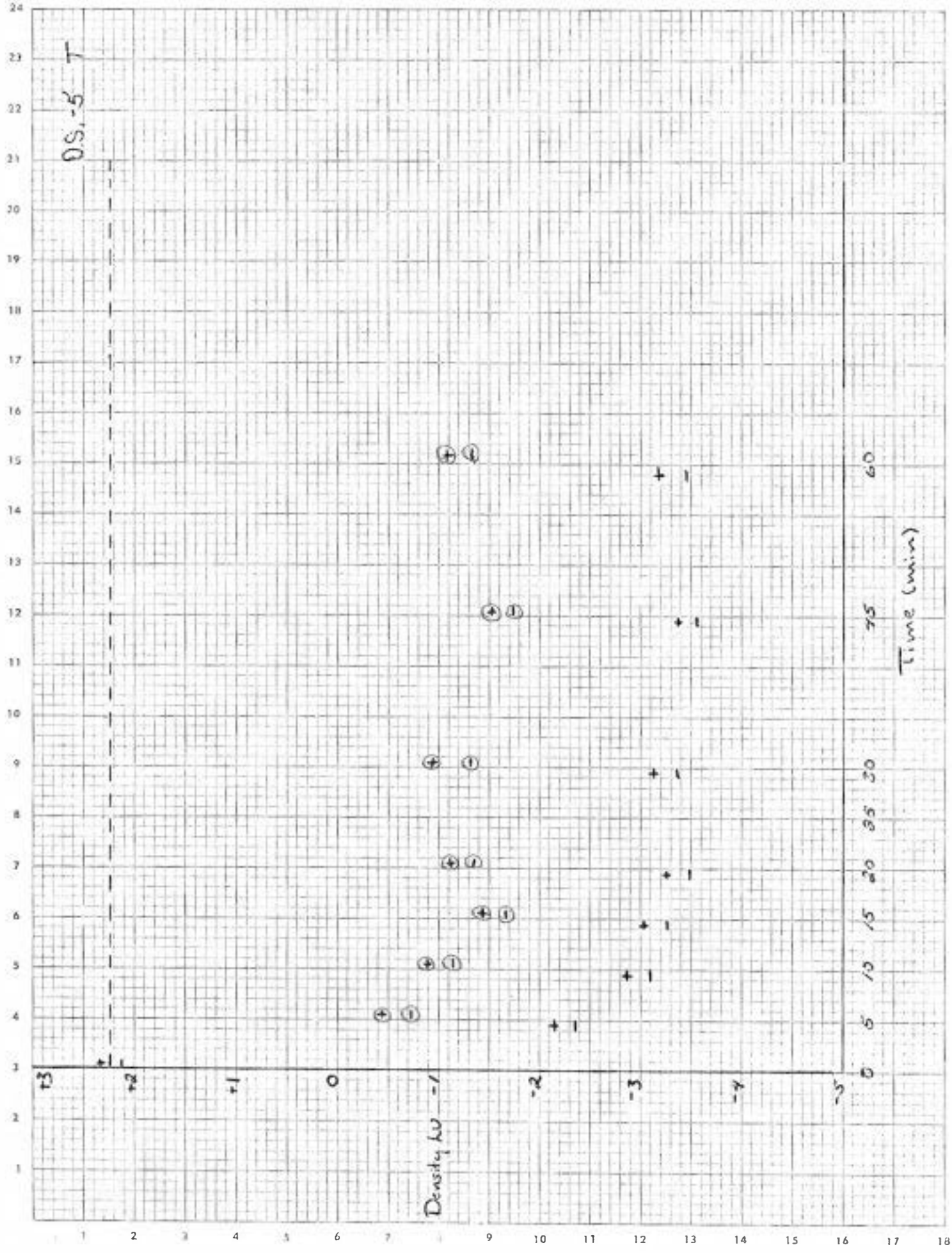
Density


OS, -5' T
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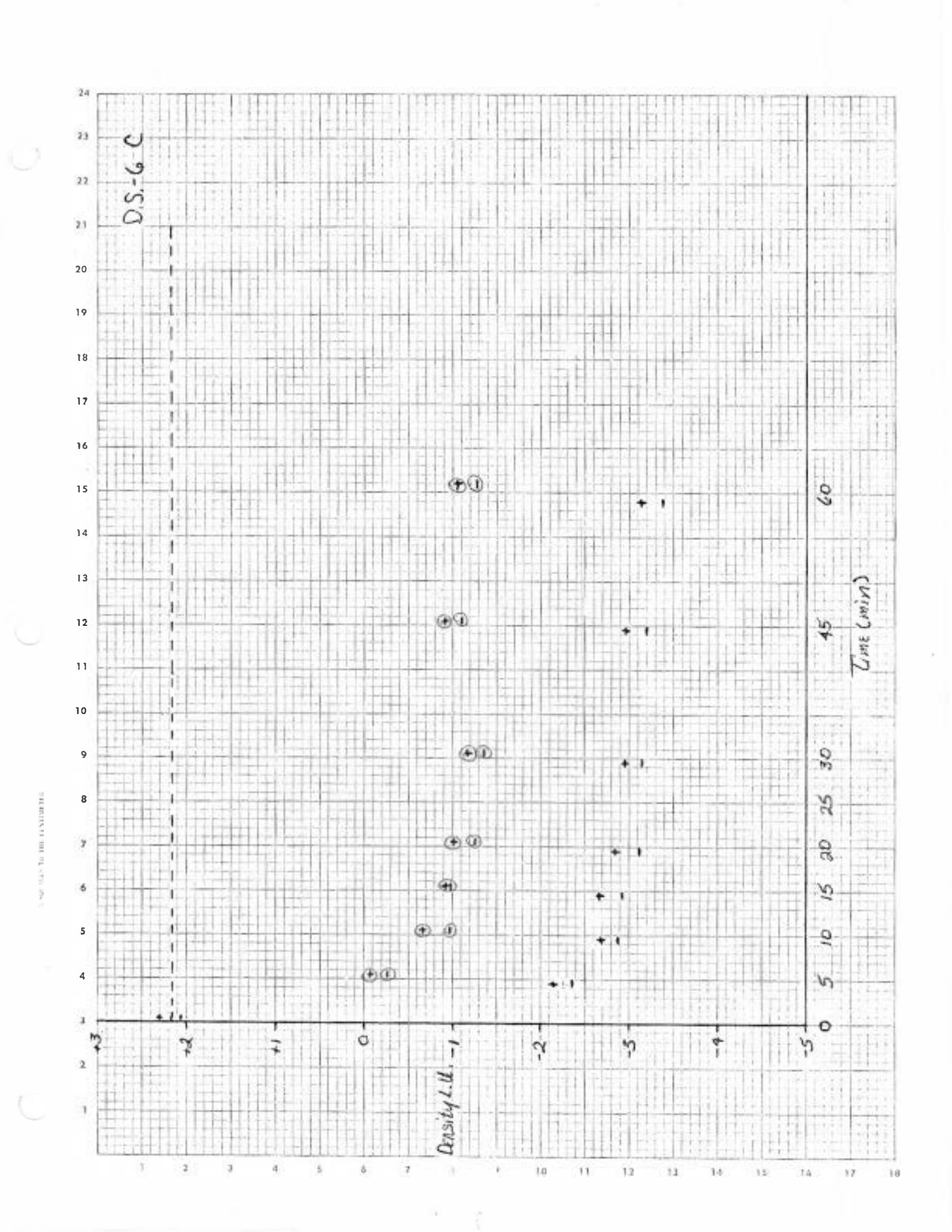
Time (min)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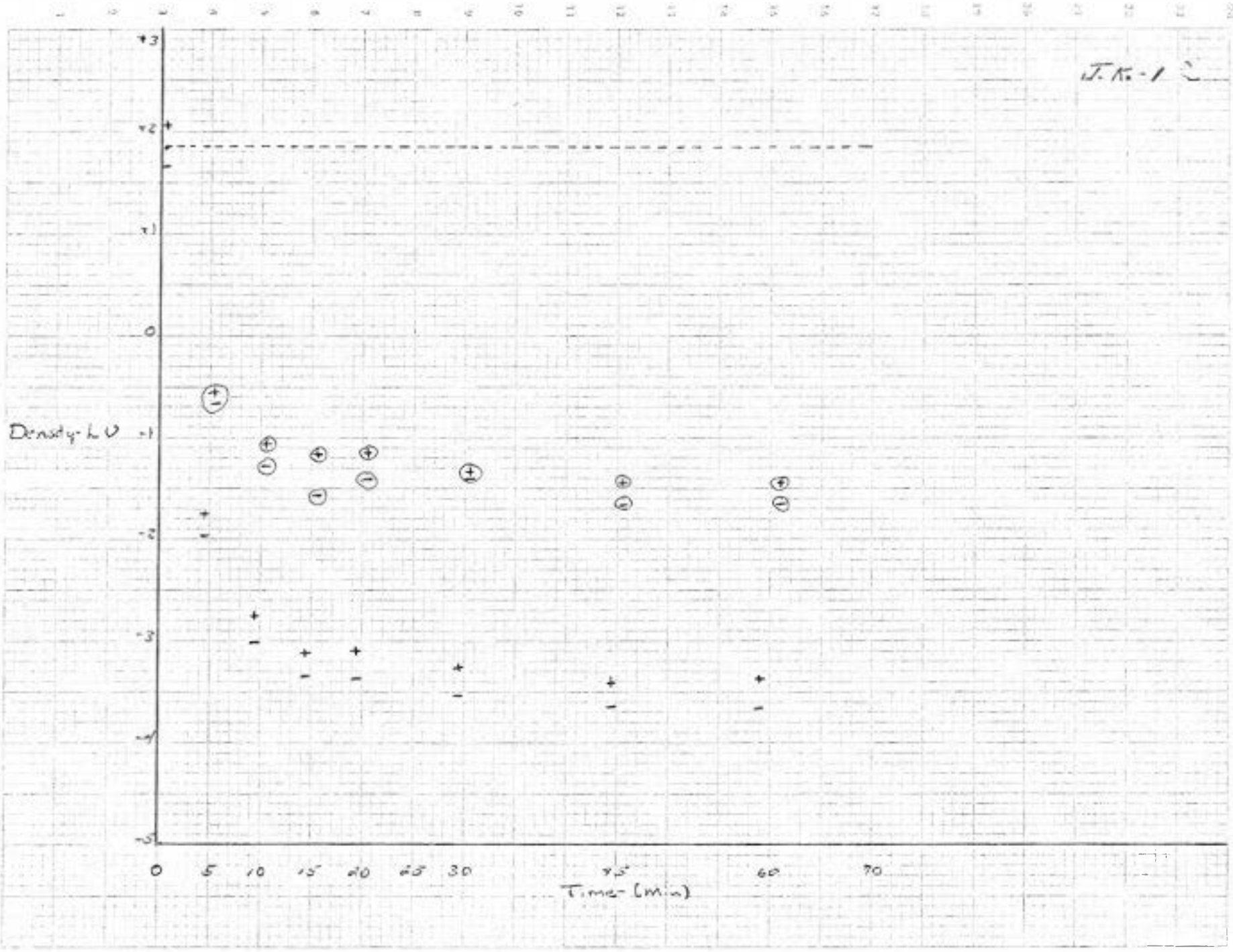
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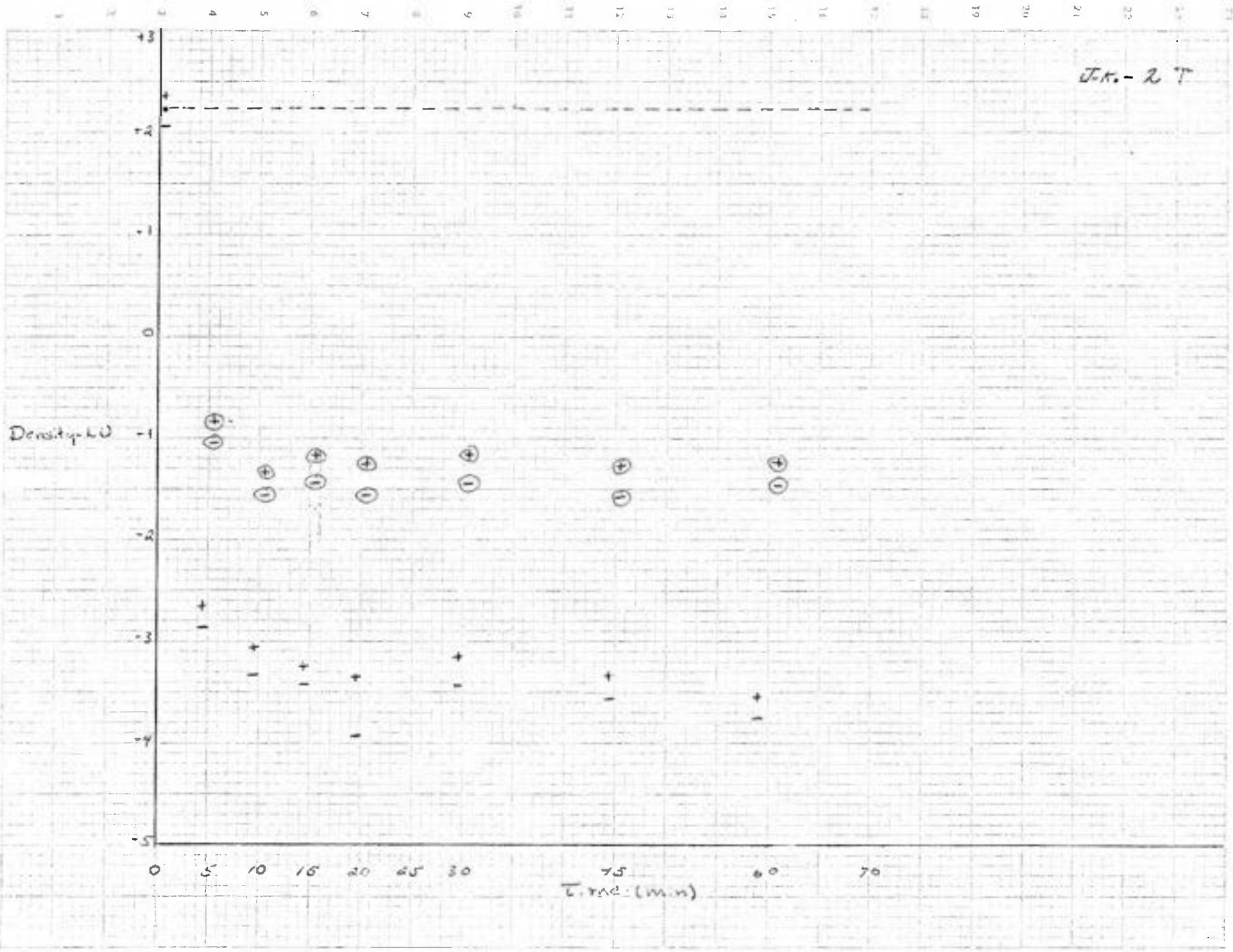
Time (min)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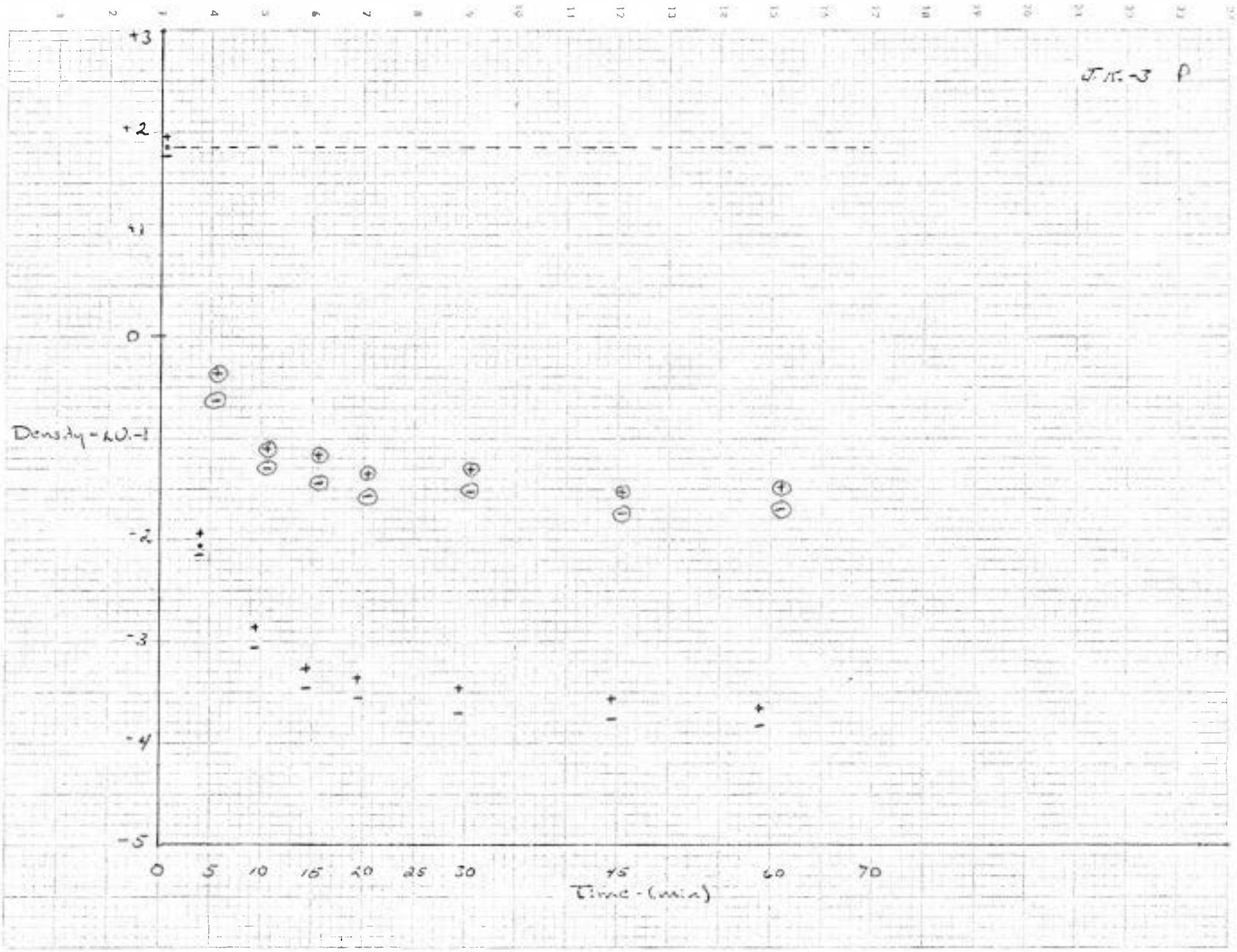
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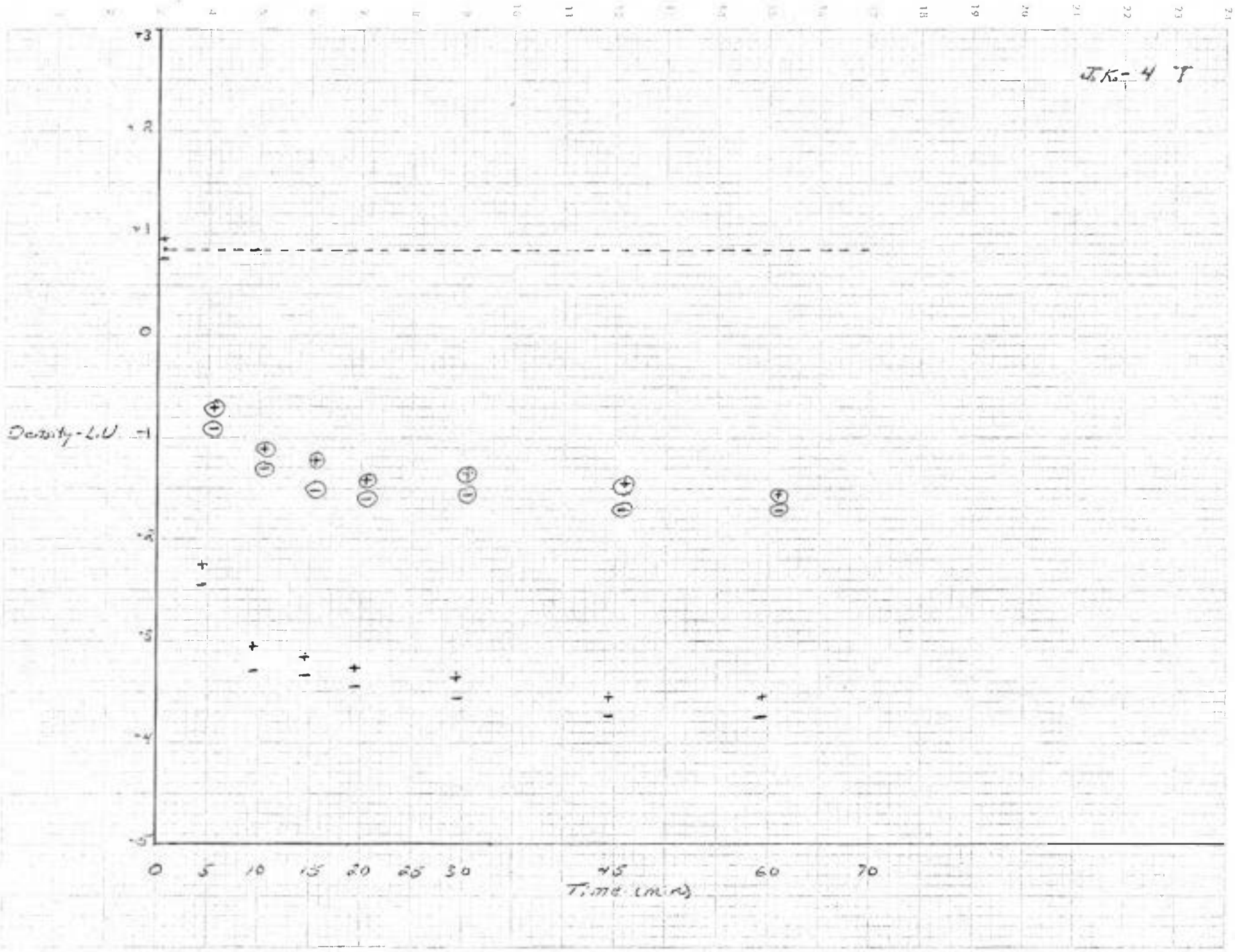
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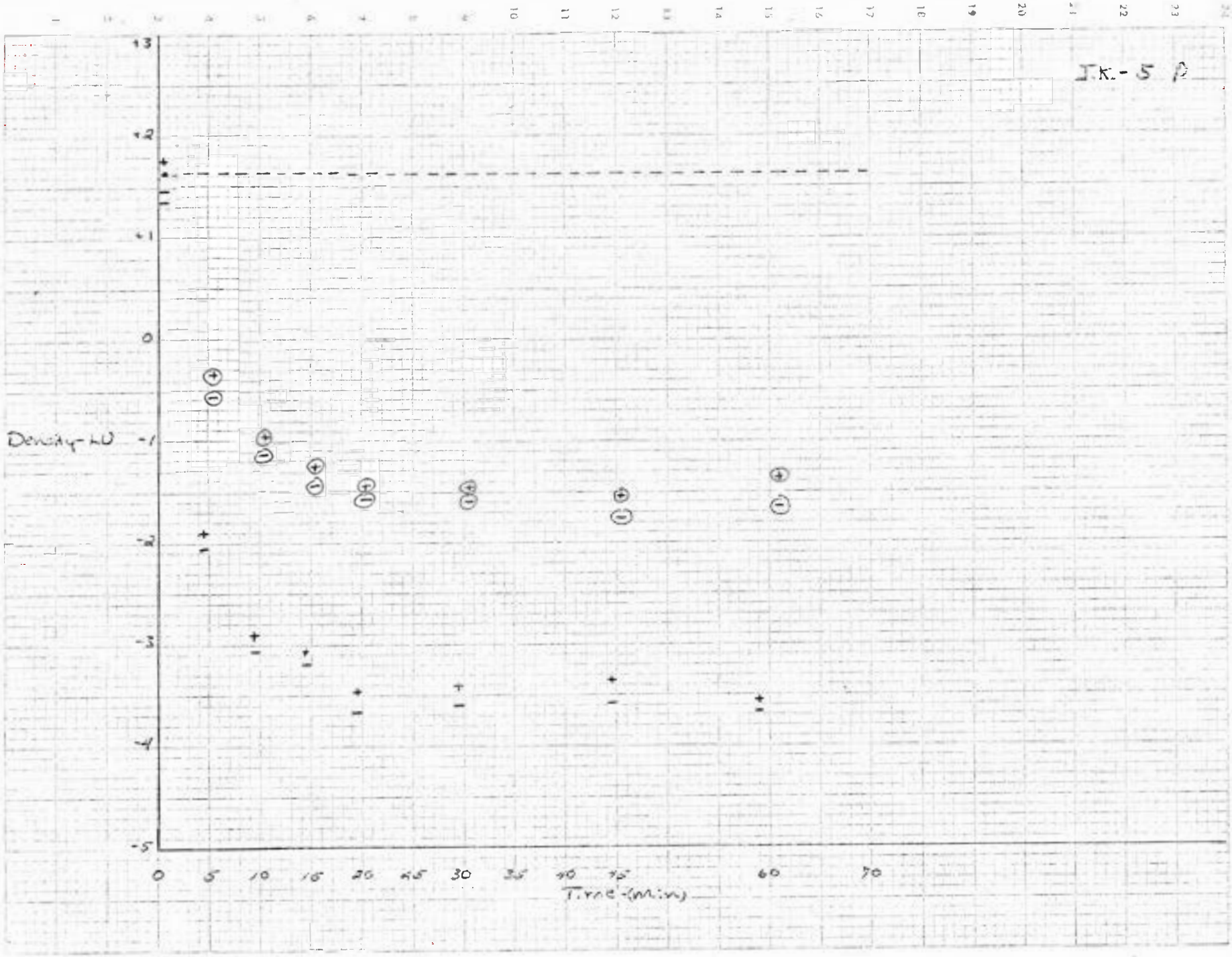
Time (min)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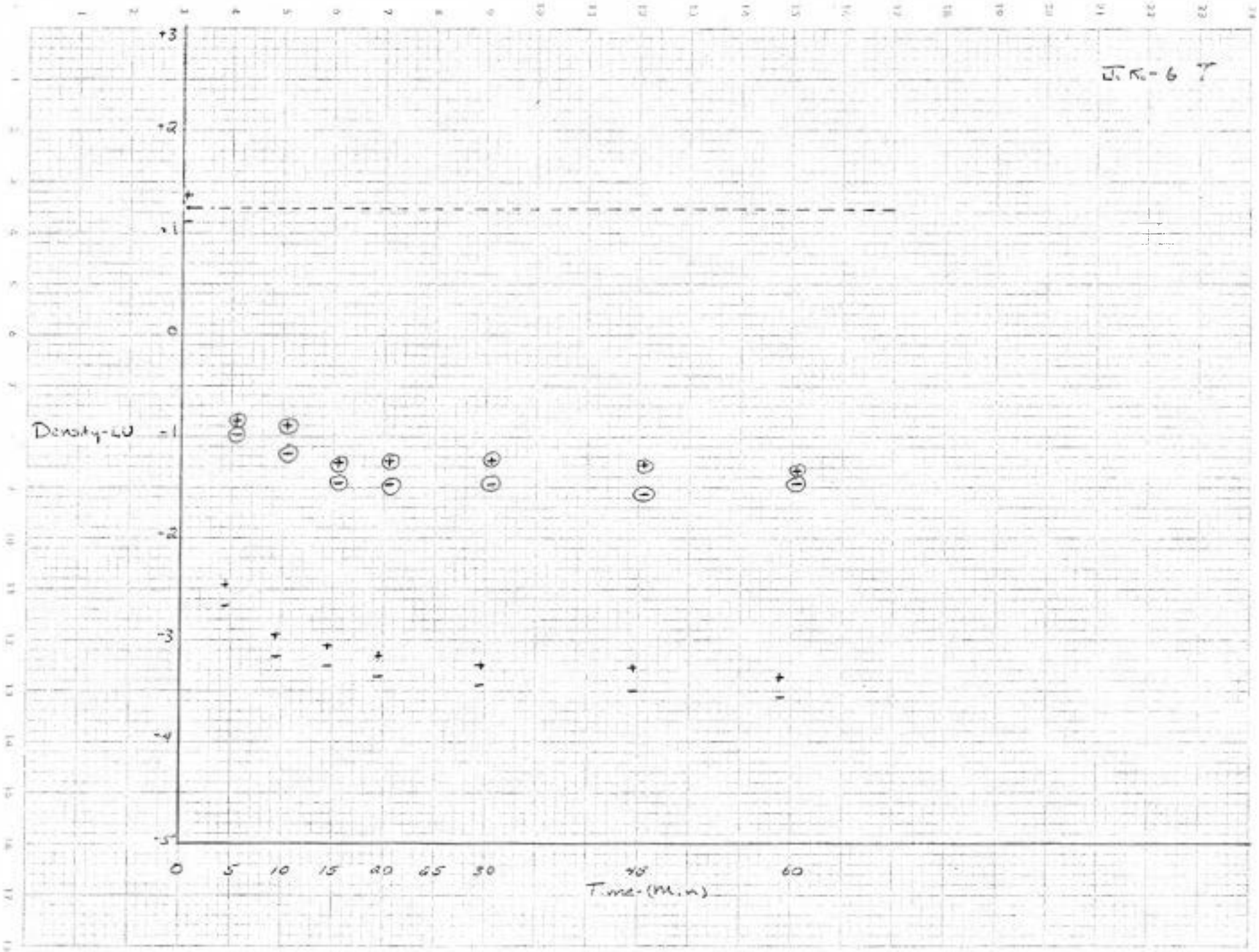
Time-(Min)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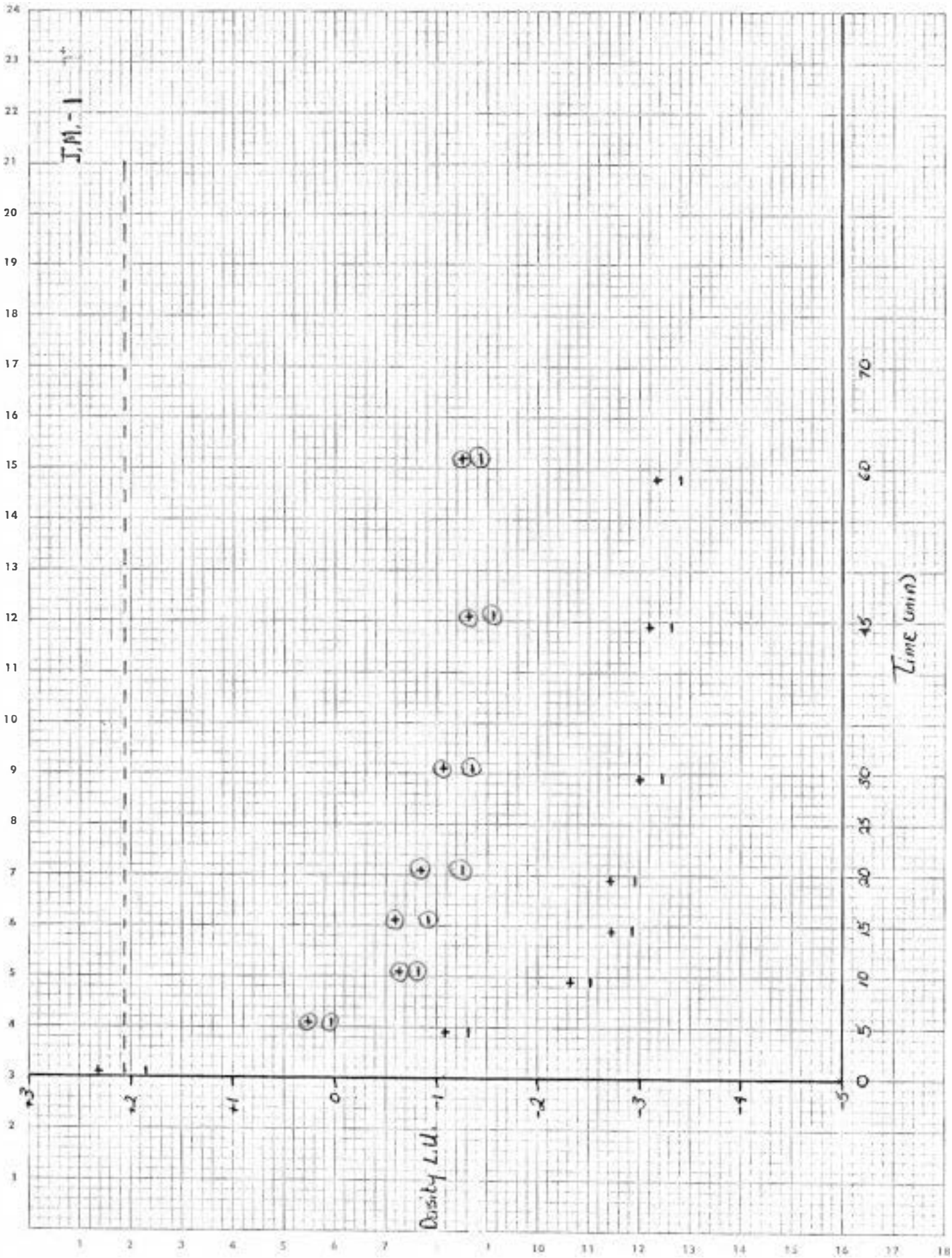
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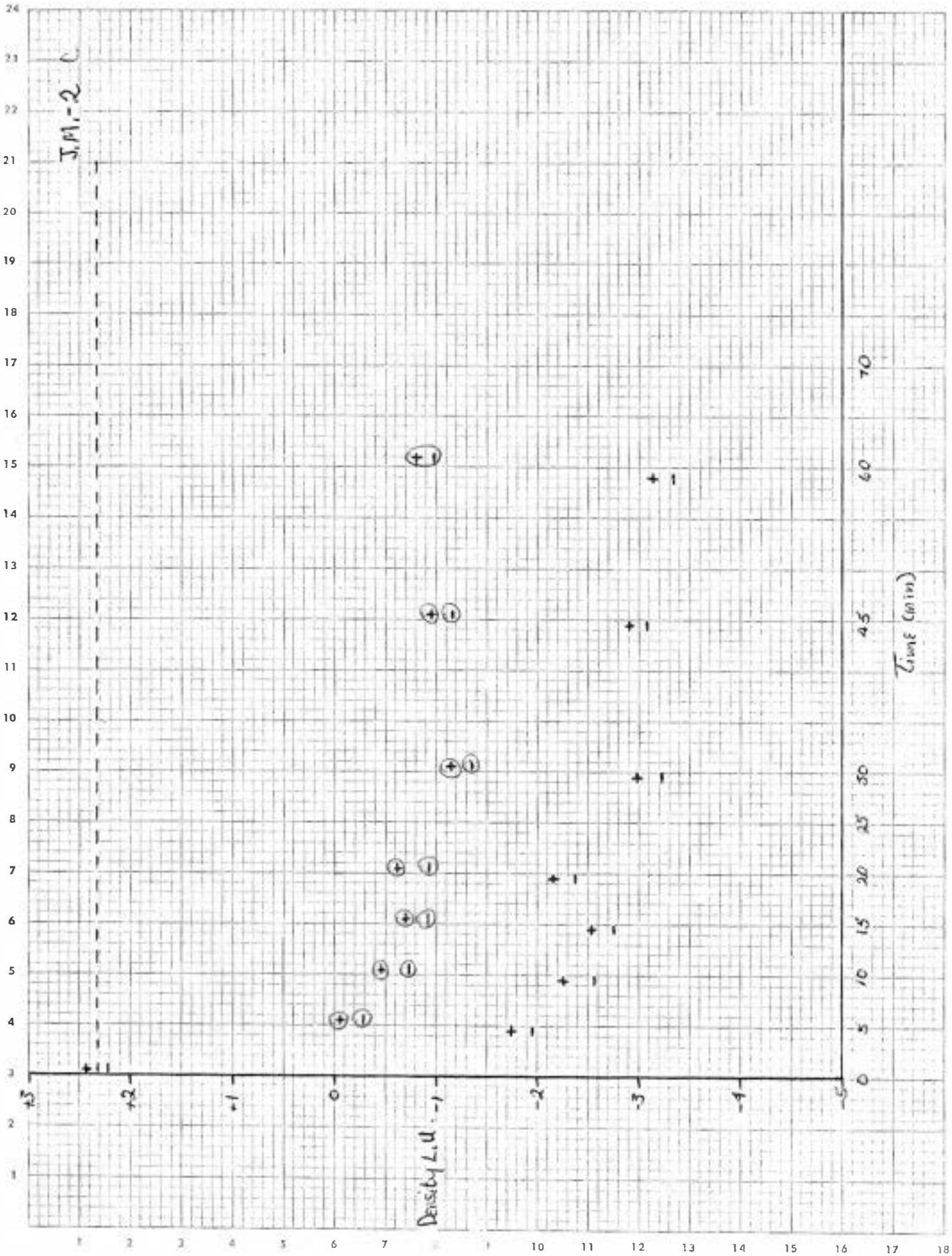
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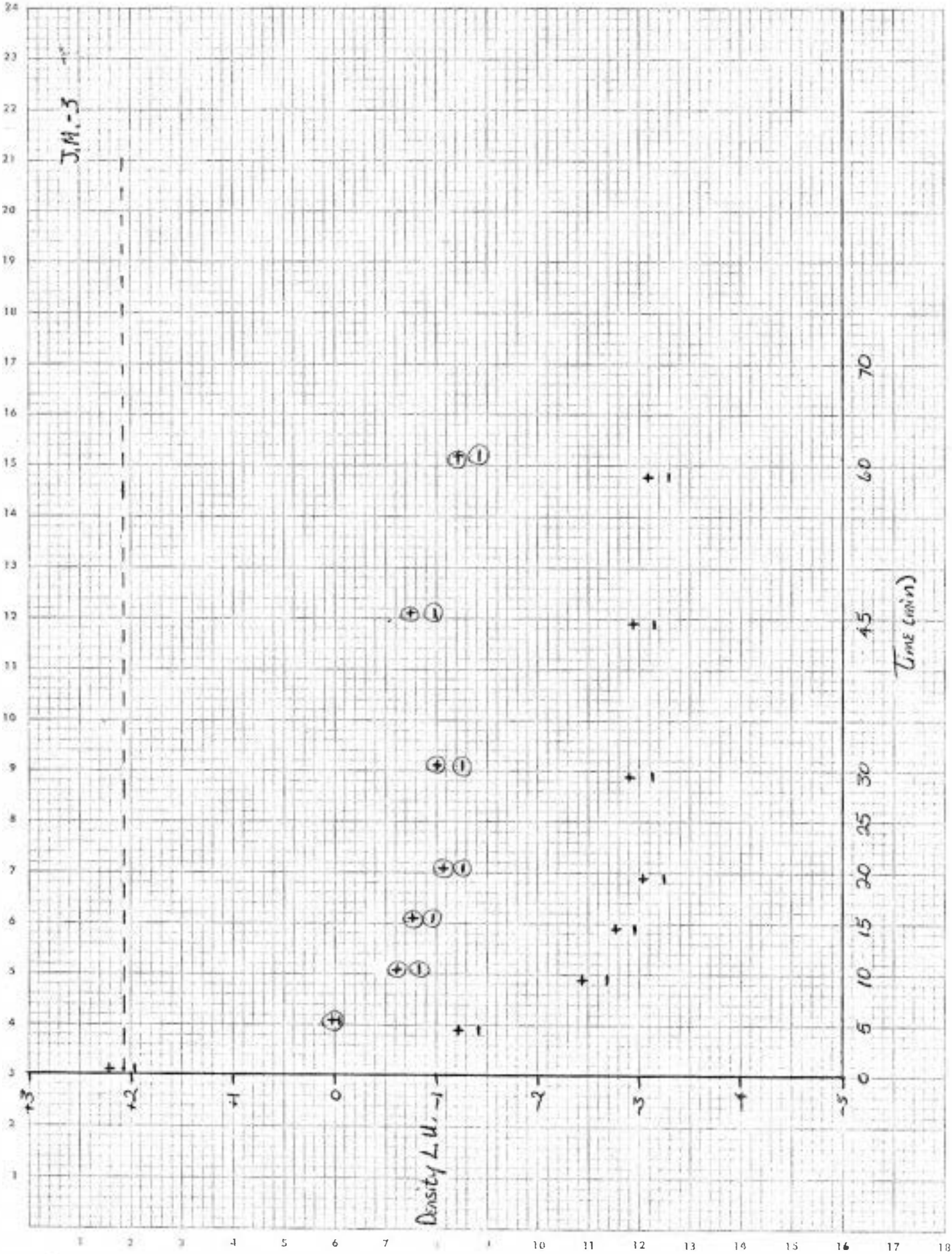
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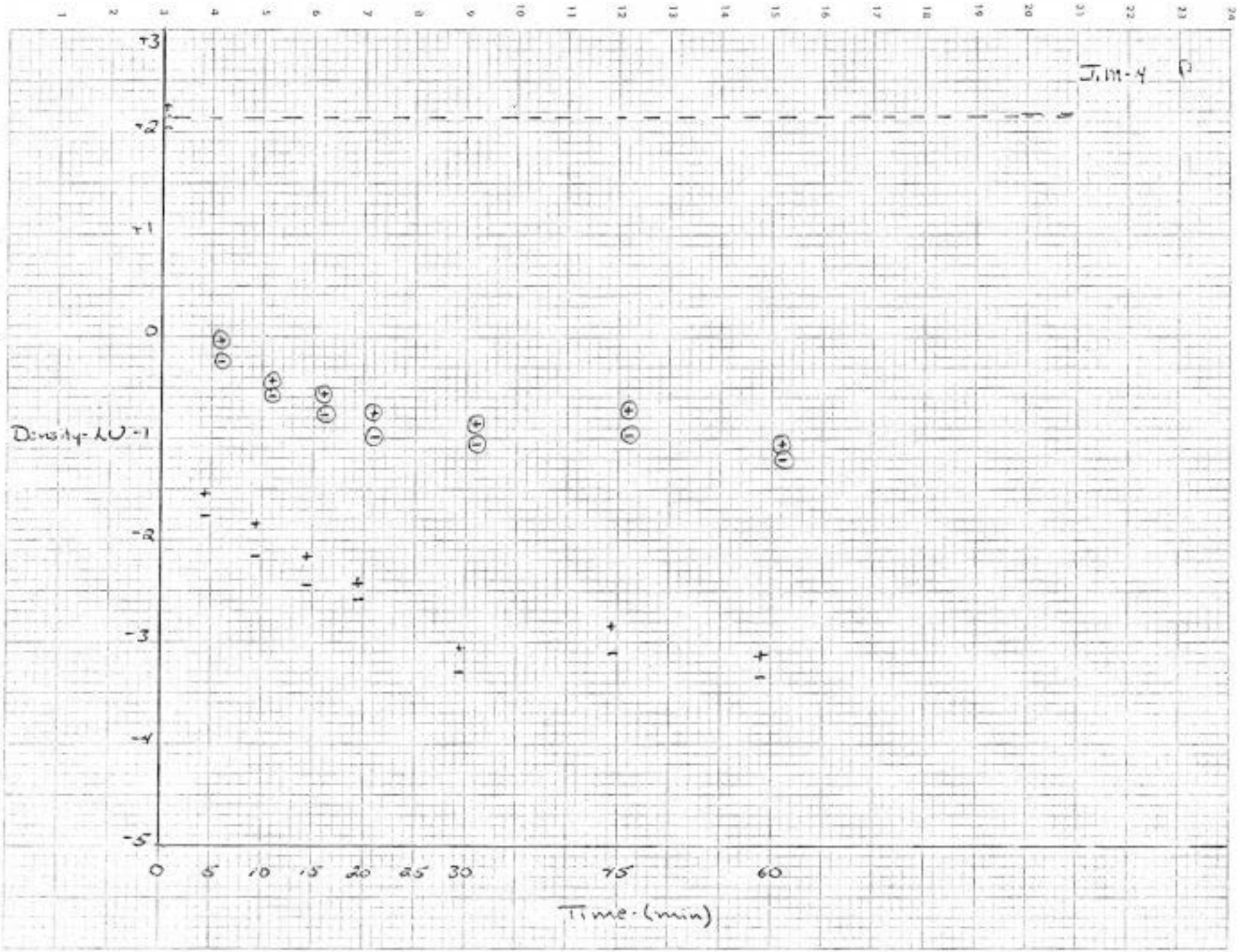
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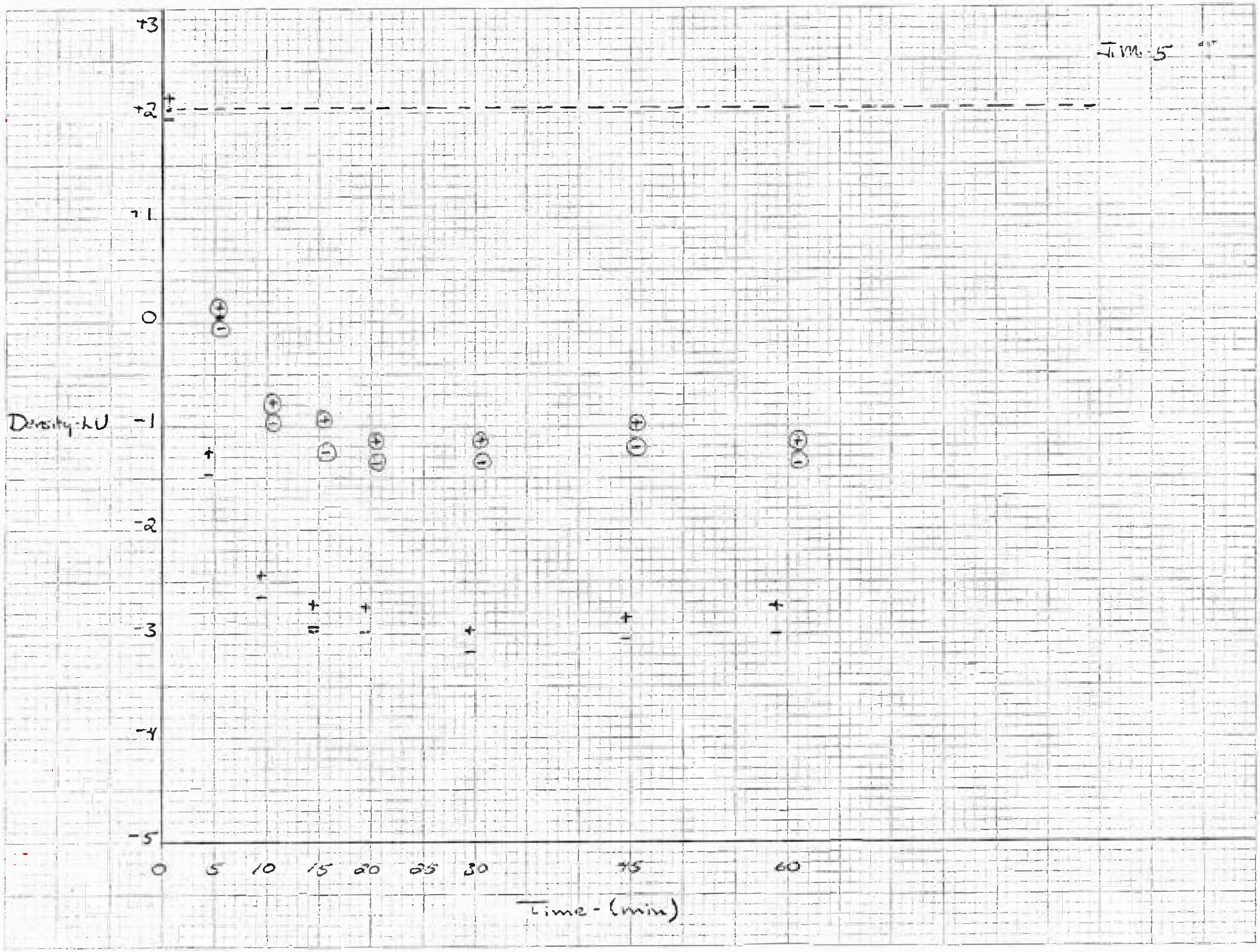
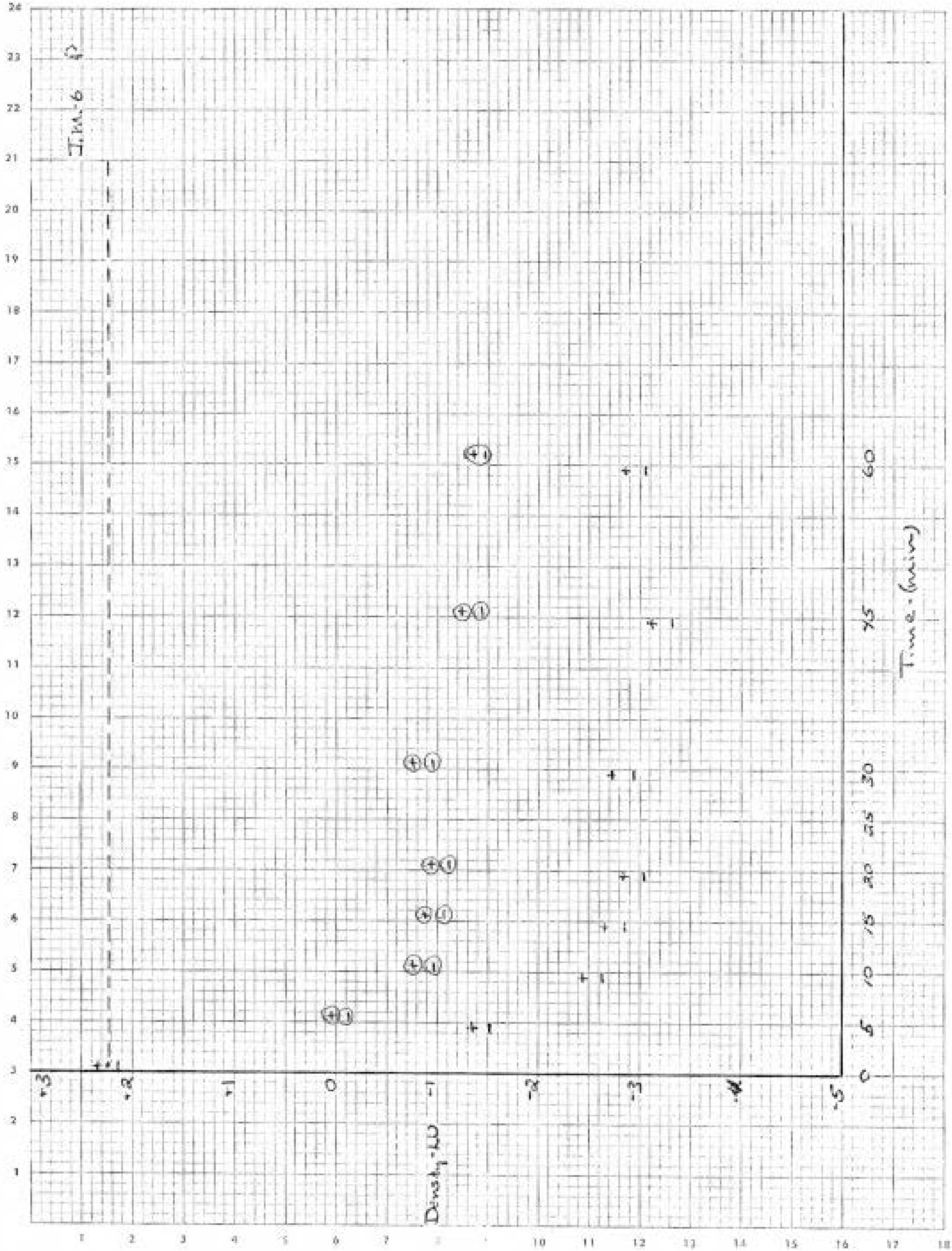
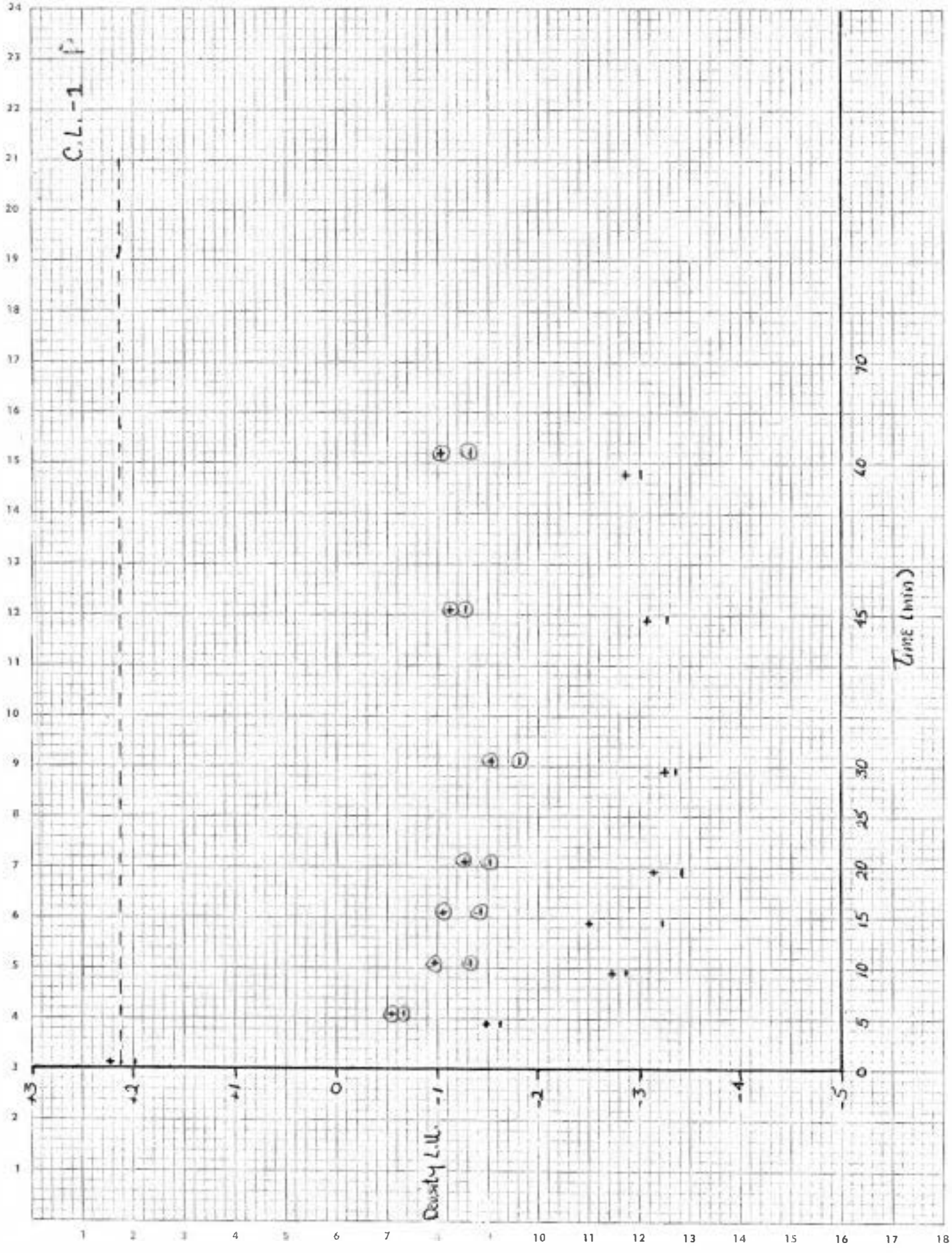
30
45
60
Time-(min)

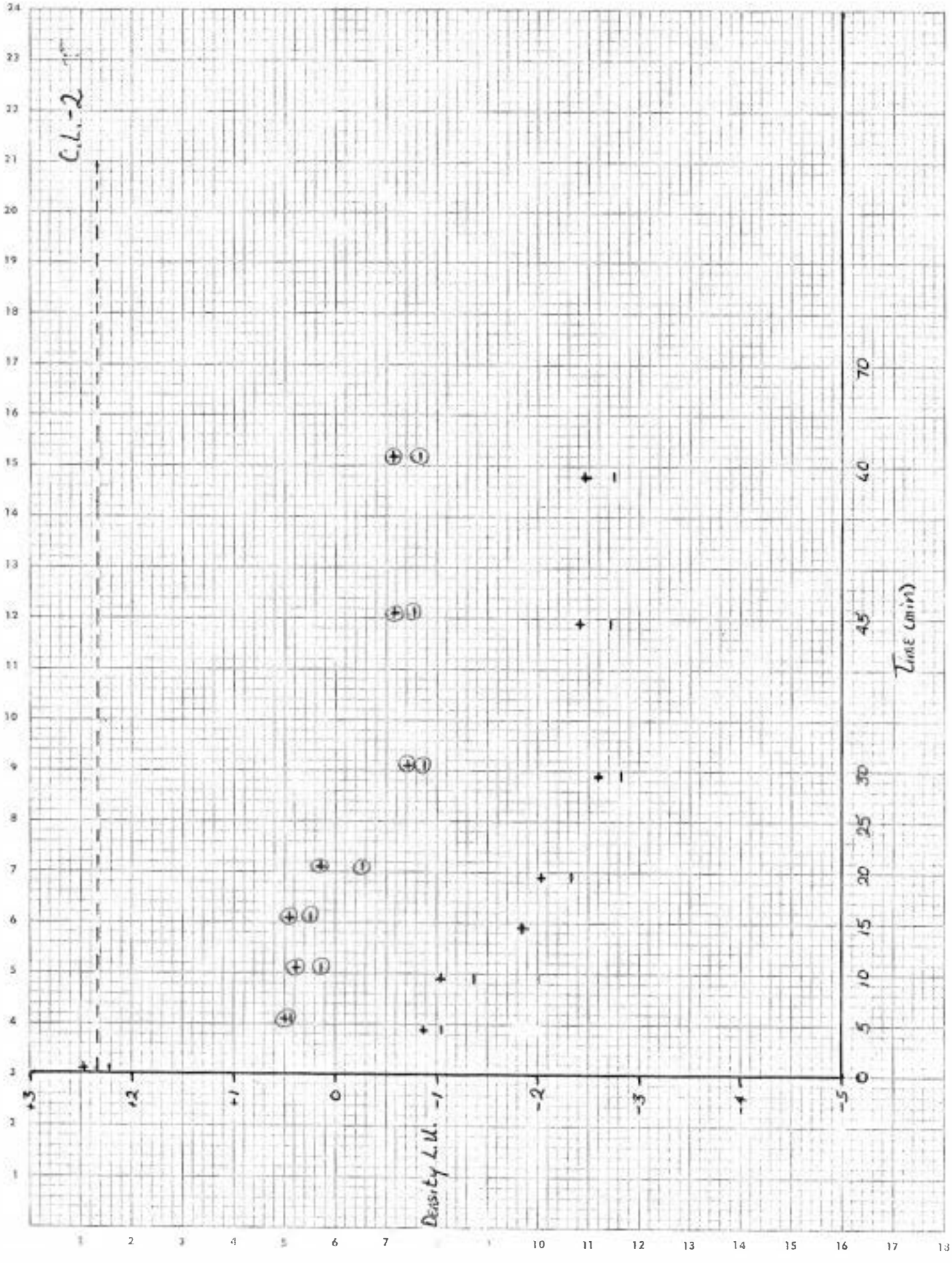


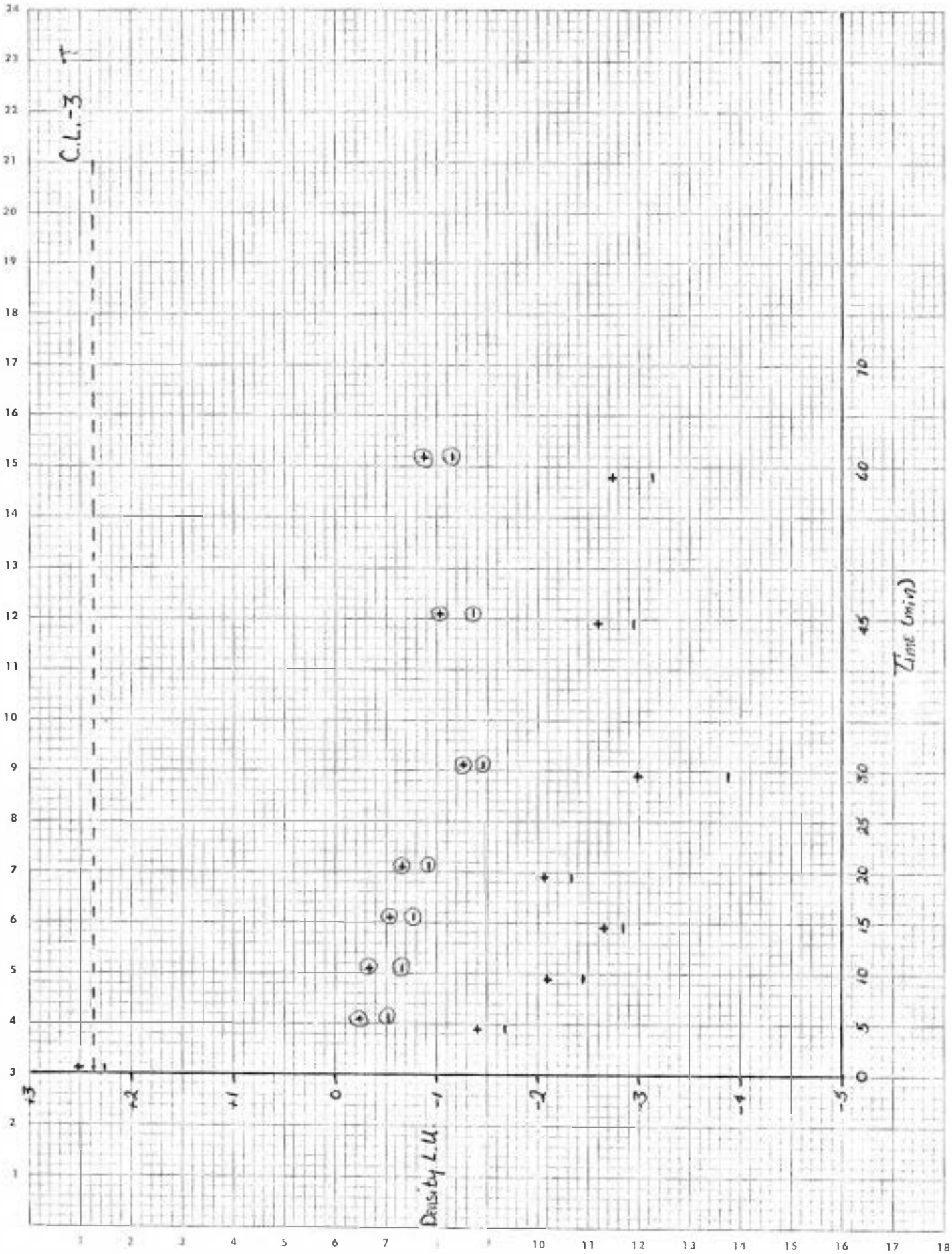
Density: kU
+3
+2
+1
0
-1
-2
-3
-4
-5
0
5
10
15
20
25
30
45
60
Time - (min)
J.M. 5

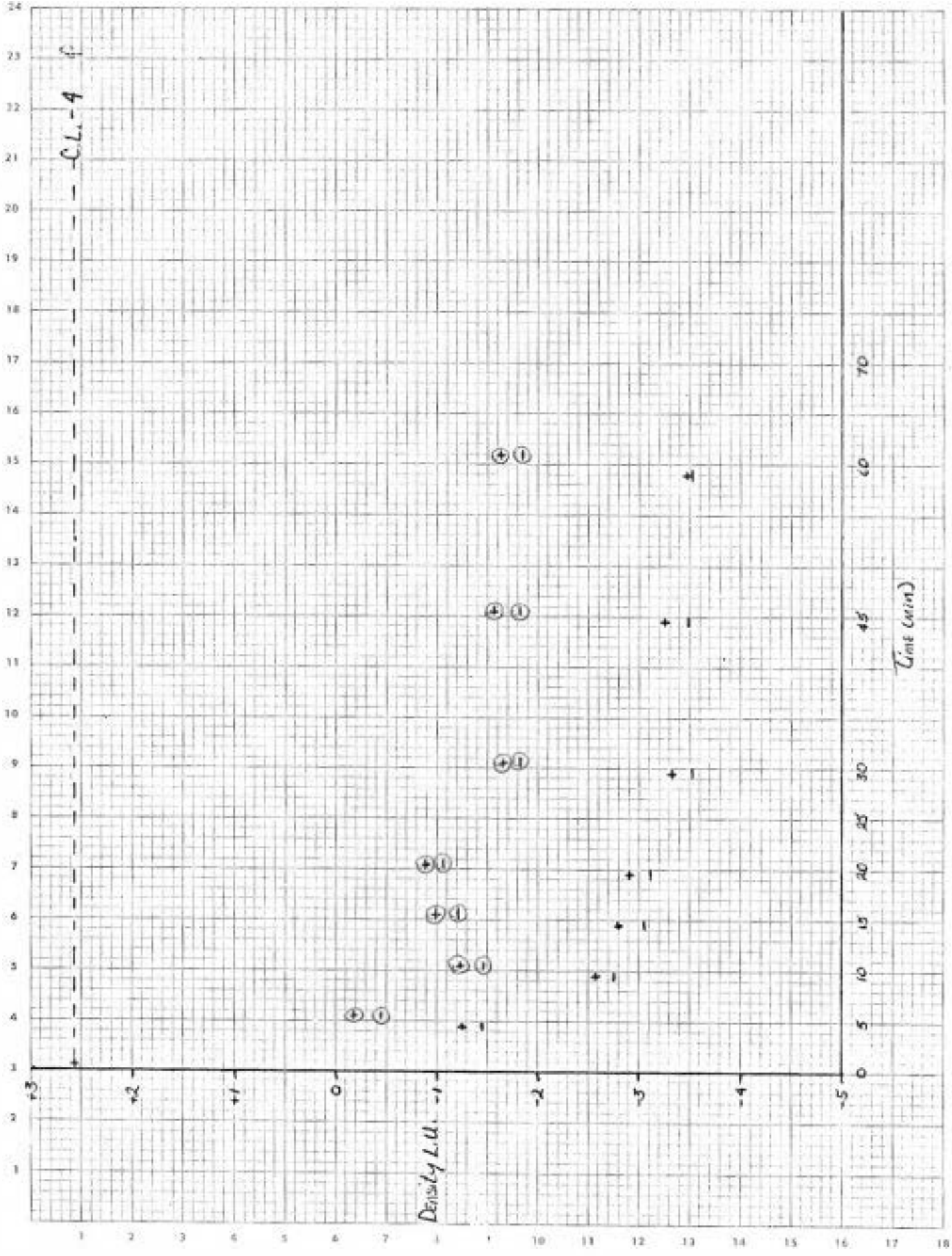


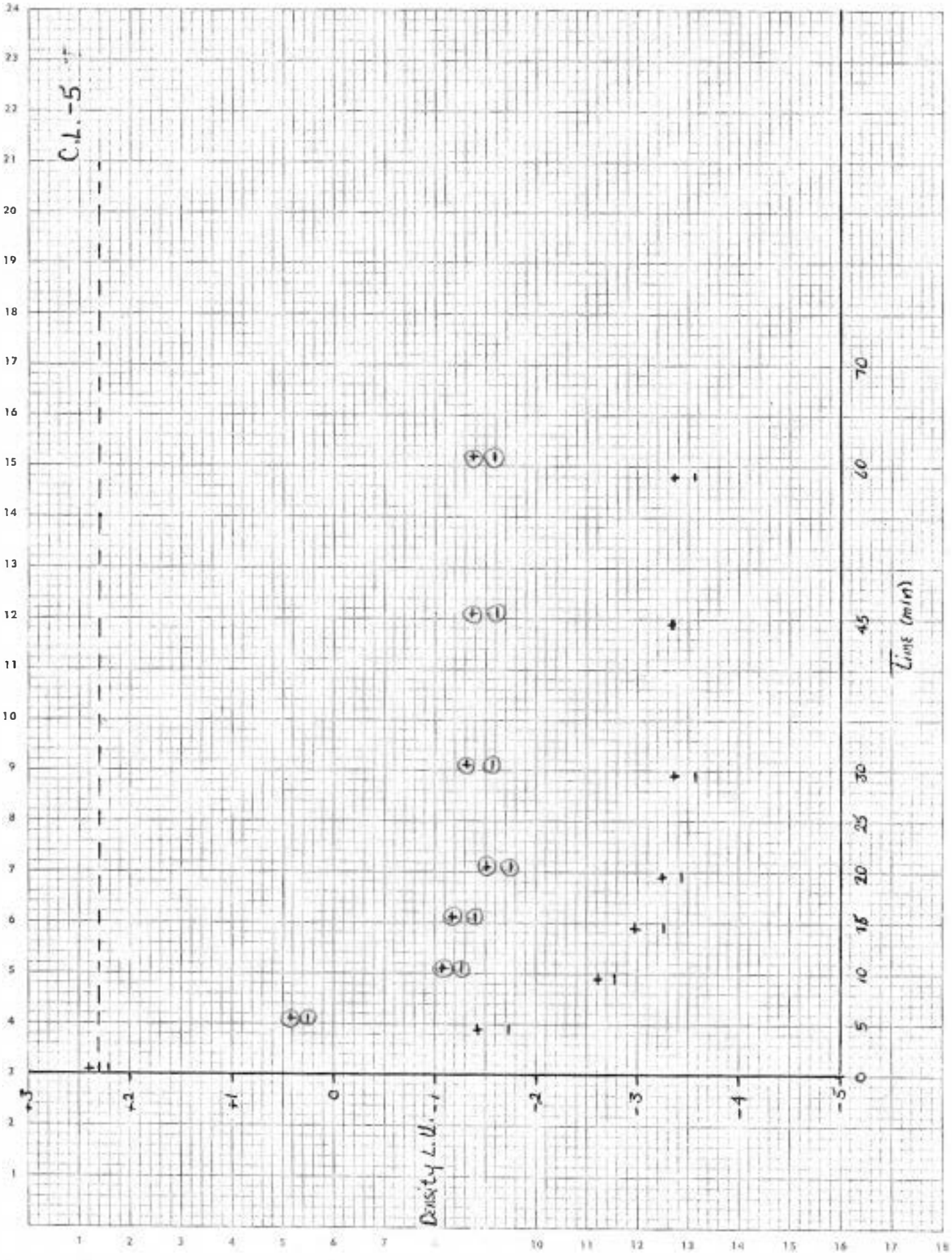
J.M.-6
Density - LD
Time (min)
+3
+2
+1
0
-1
-2
-3
-4
-5
0
5
10
15
20
25
30
45
60

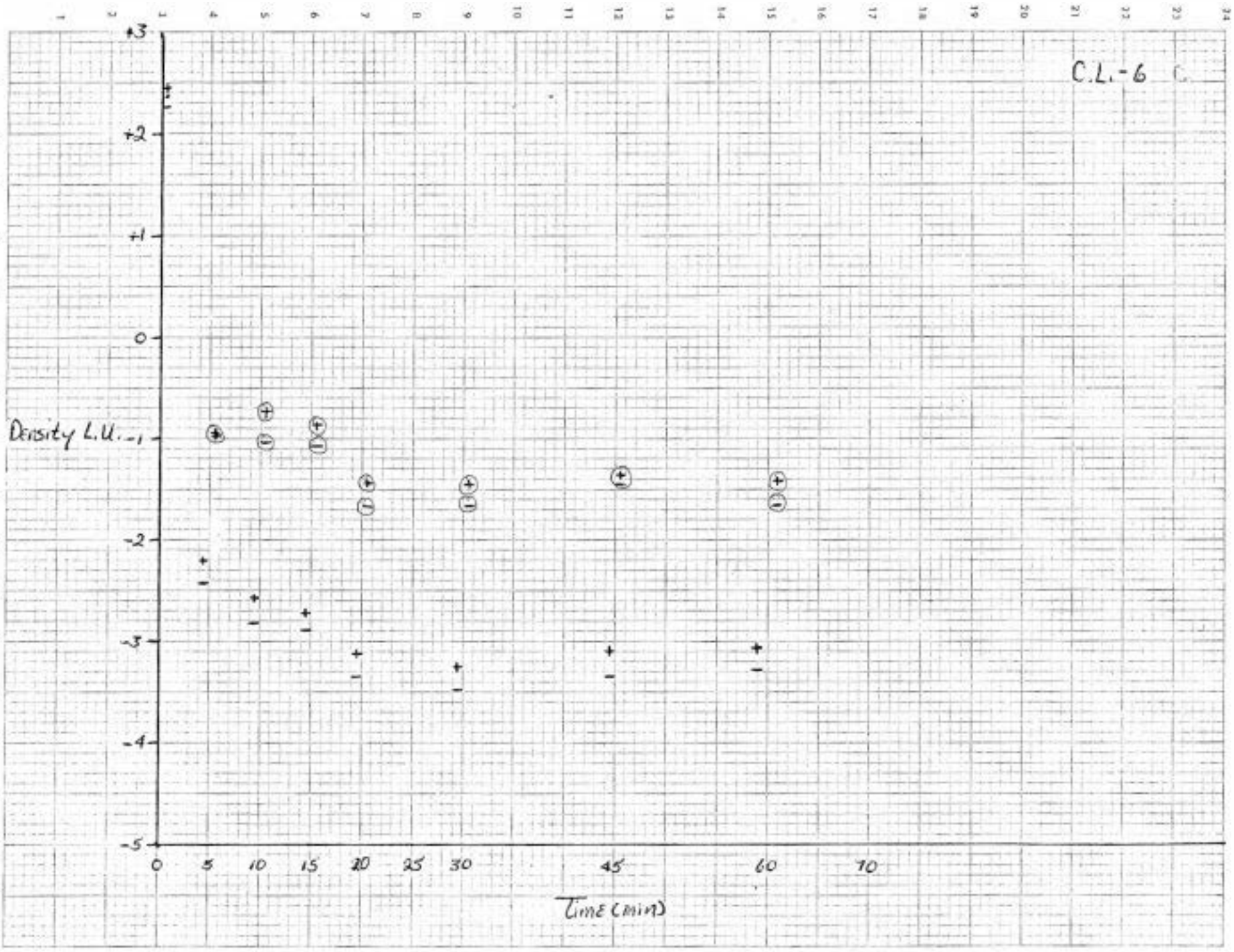

C.L. -1
Density L.U.
Time (min)

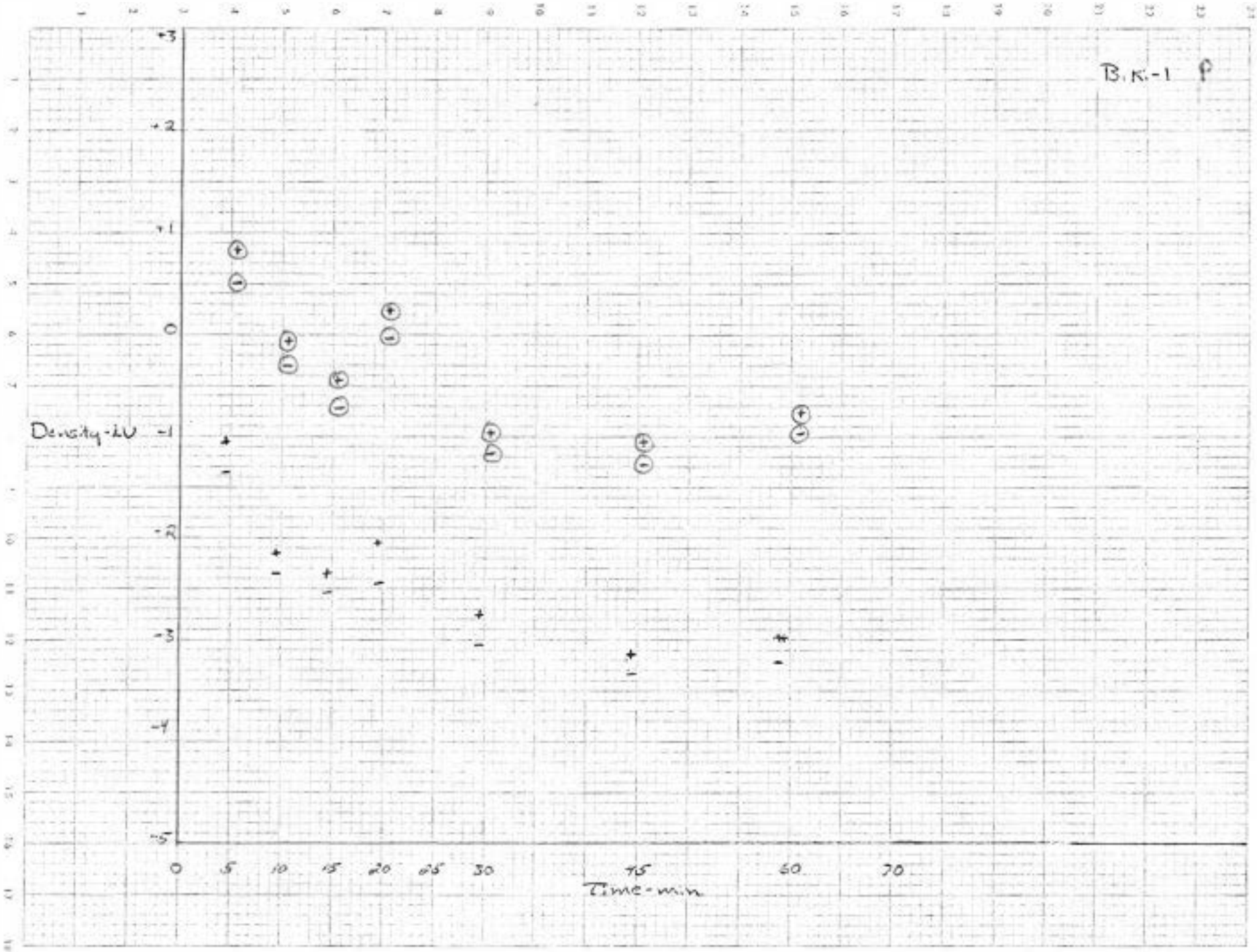

C.L.-2
Density L.U.
Time (min)

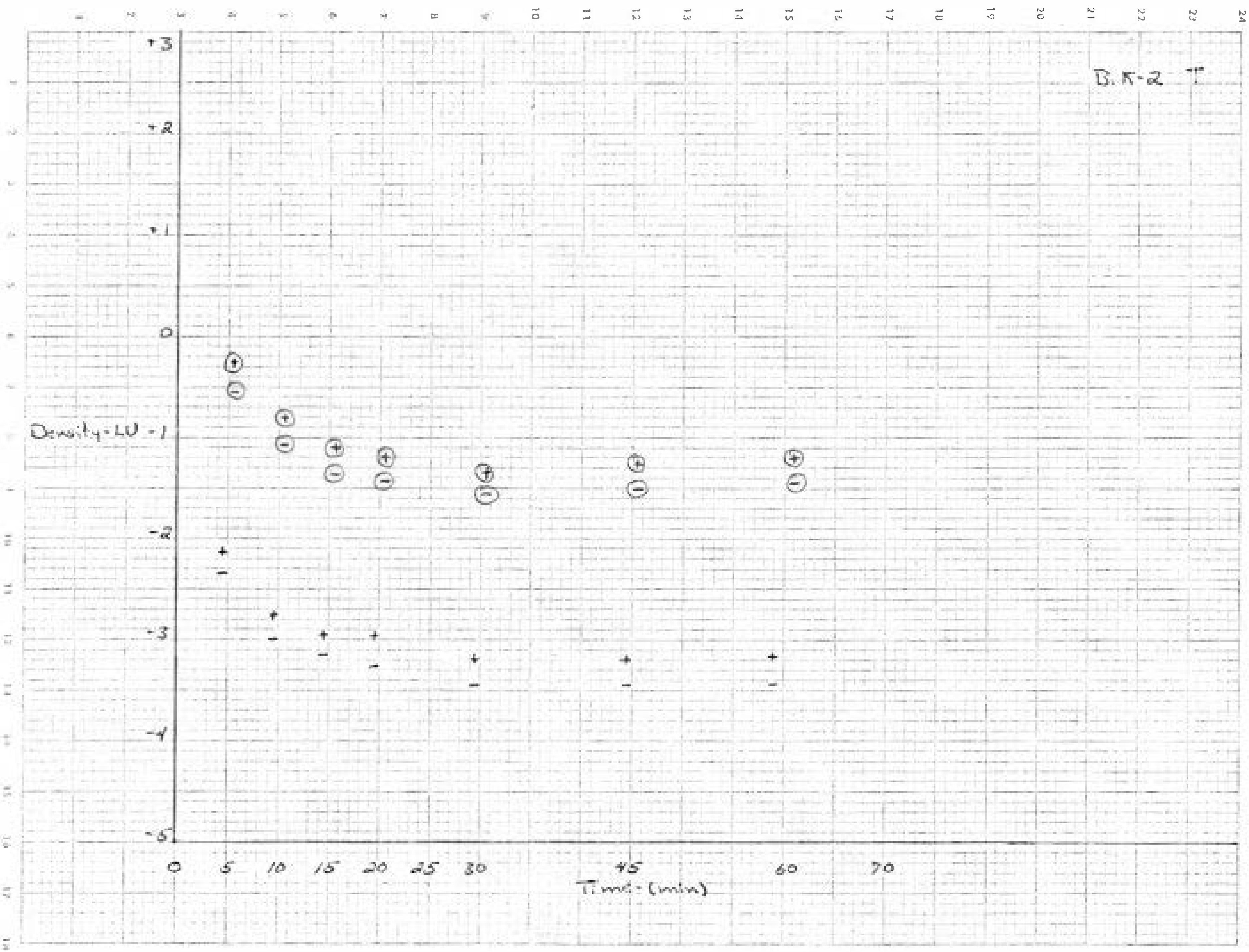

C.L.-3
Density L.U.
Time (min)

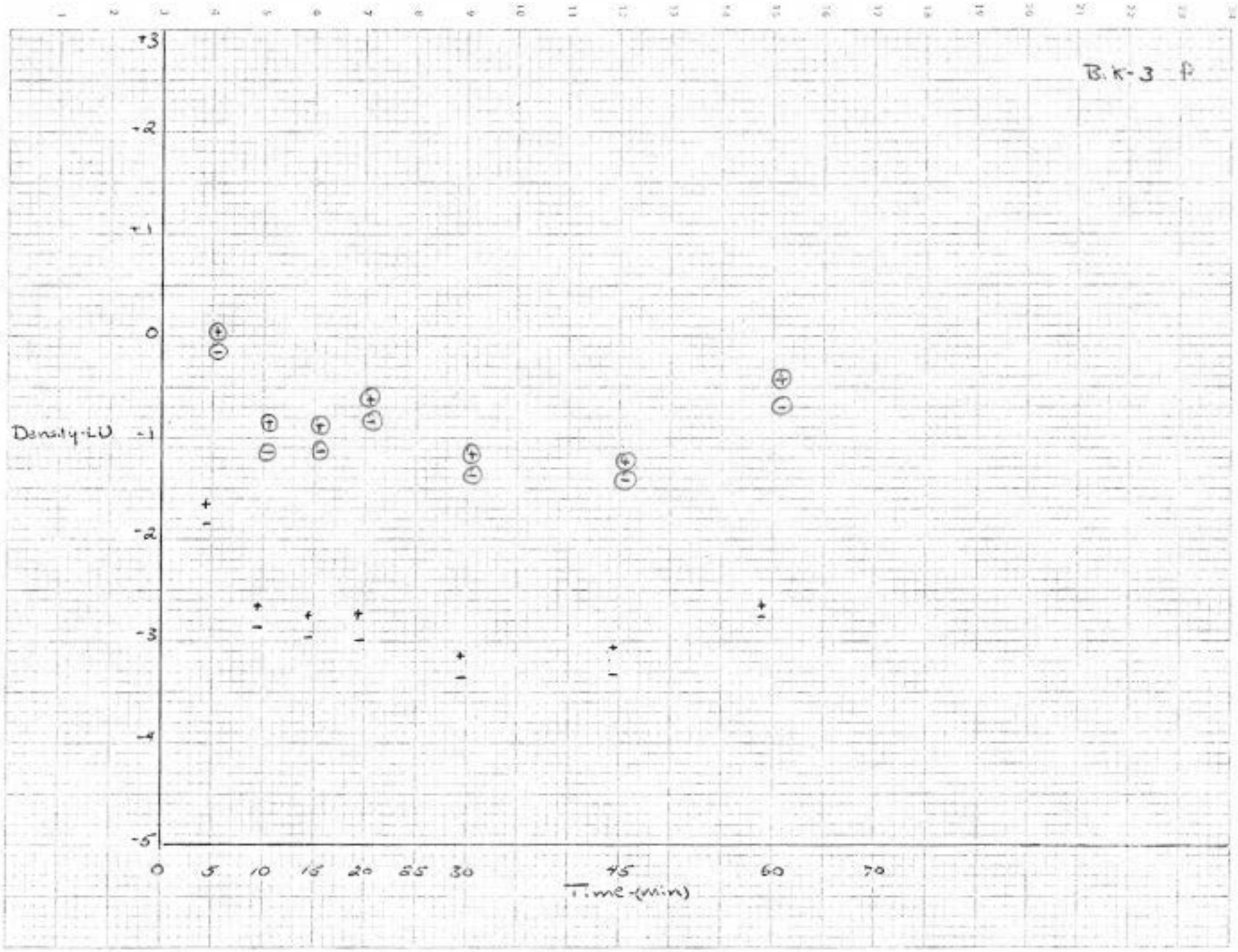

CL-4
Density L.U.
Time (min)


C.L. -5
Density C.U. -4
Time (min)


C.L.-6
+3
+2
+1
0
-1
-2
-3
-4
-5
Density L.U.
0
5
10
15
20
25
30
45
60
70
Time (min)


B.K.-1
+3
+2
+1
0
-1
-2
-3
-4
-5
Density-ΔV
0
5
10
15
20
25
30
45
60
70
Time-min.


B.K.2 T
Density LU 1
Time (min)


B.K-3 P
+3
+2
+1
0
-1
-2
-3
-4
-5
Density-LU
0
5
10
15
20
25
30
45
60
70
Time-(min)

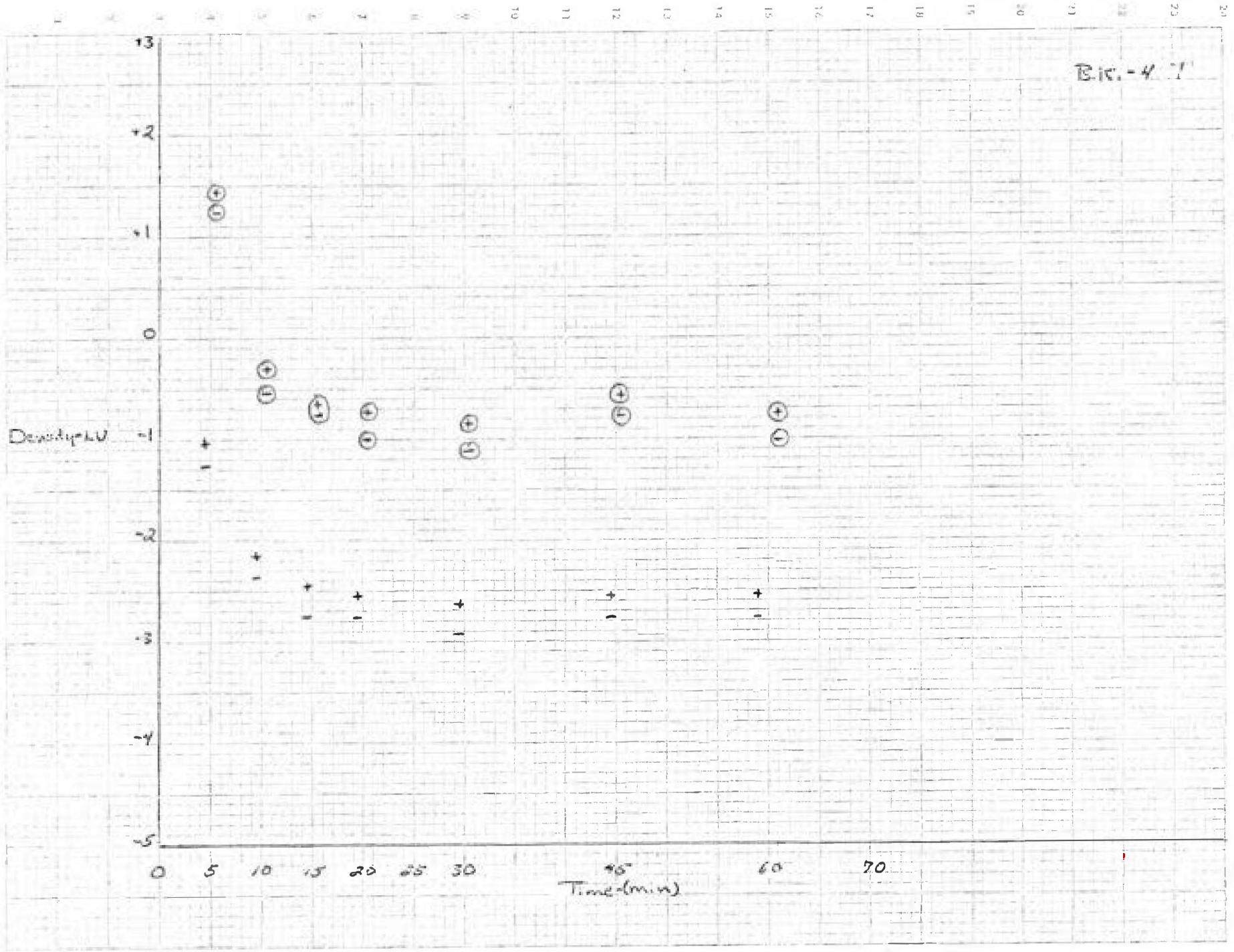
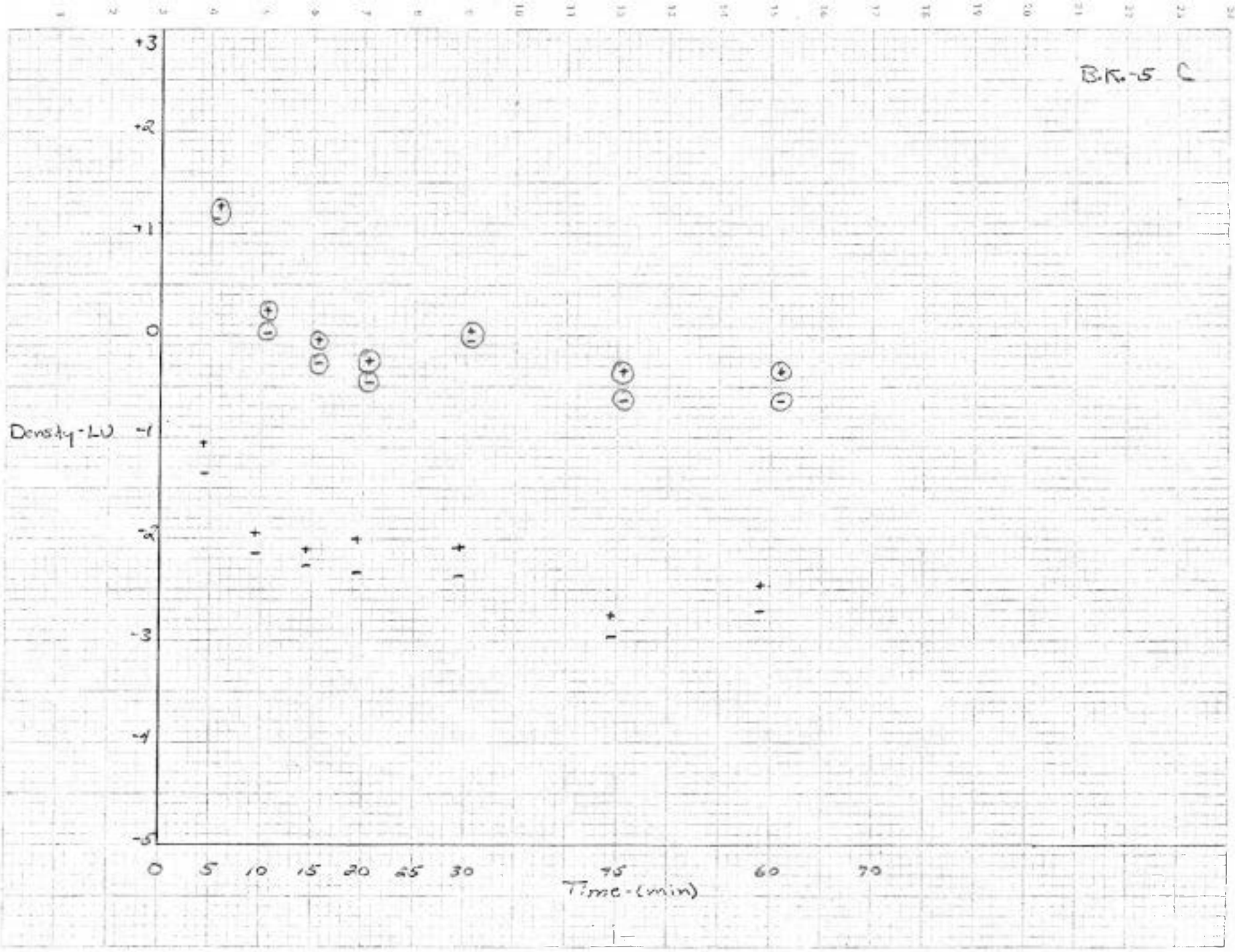
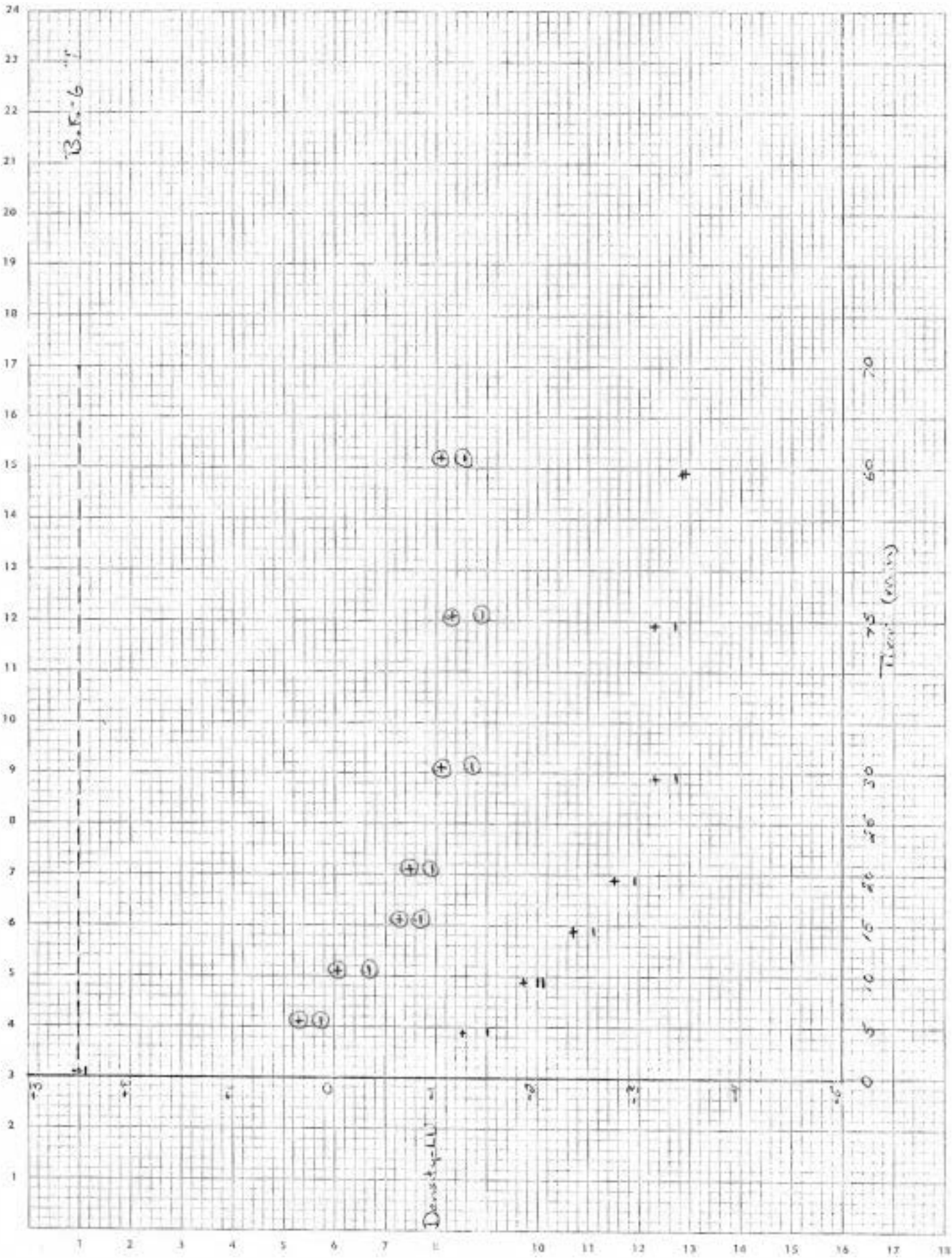
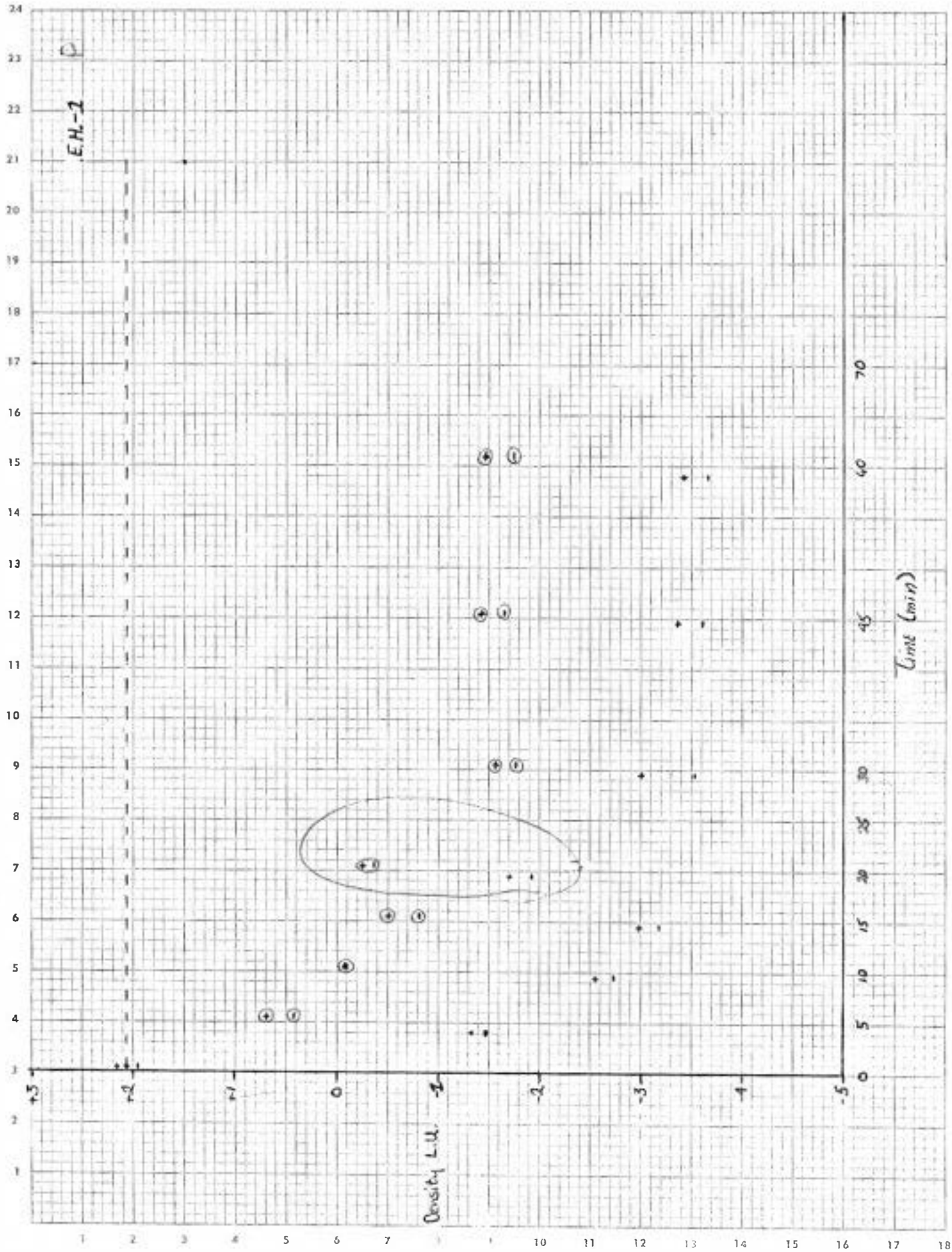
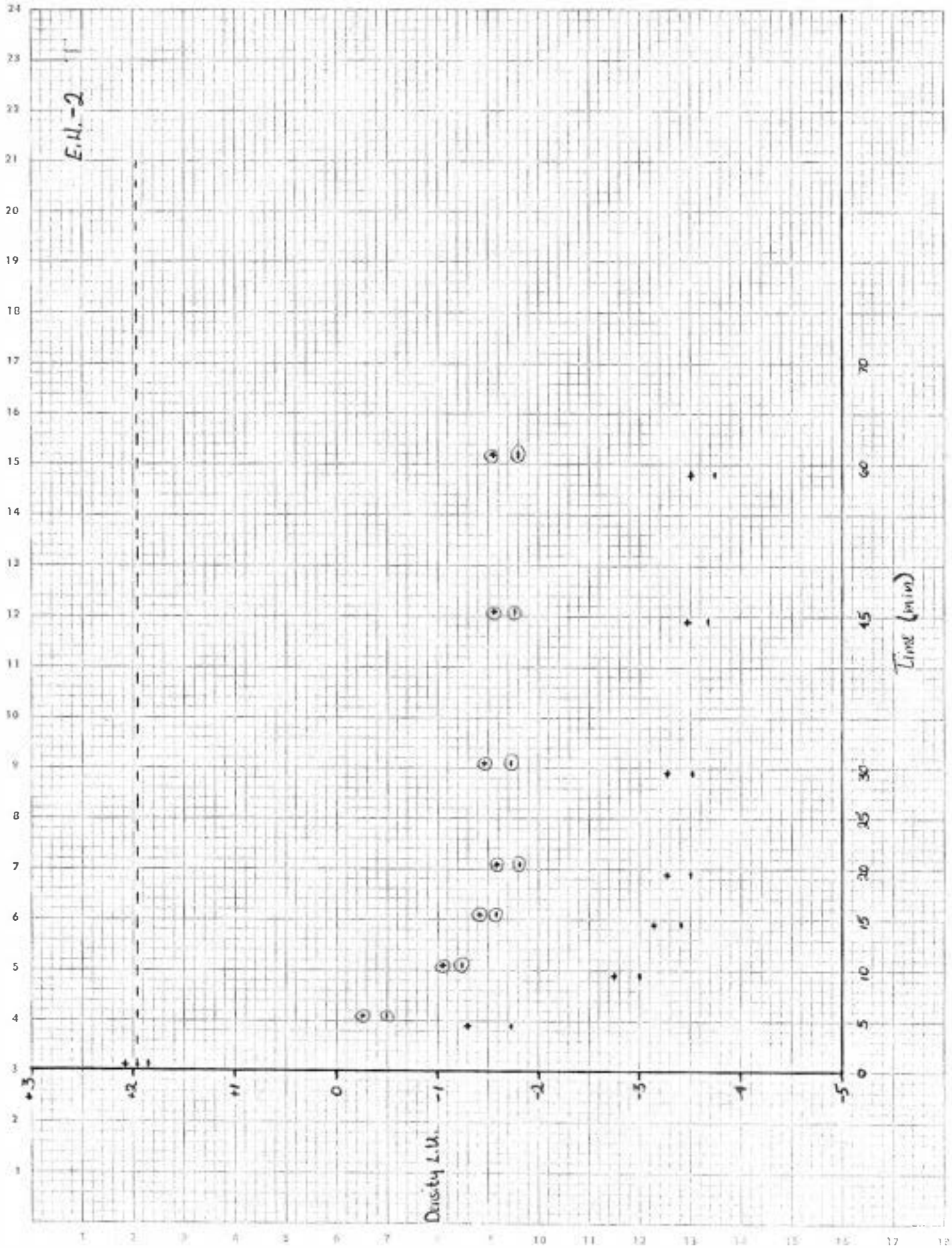


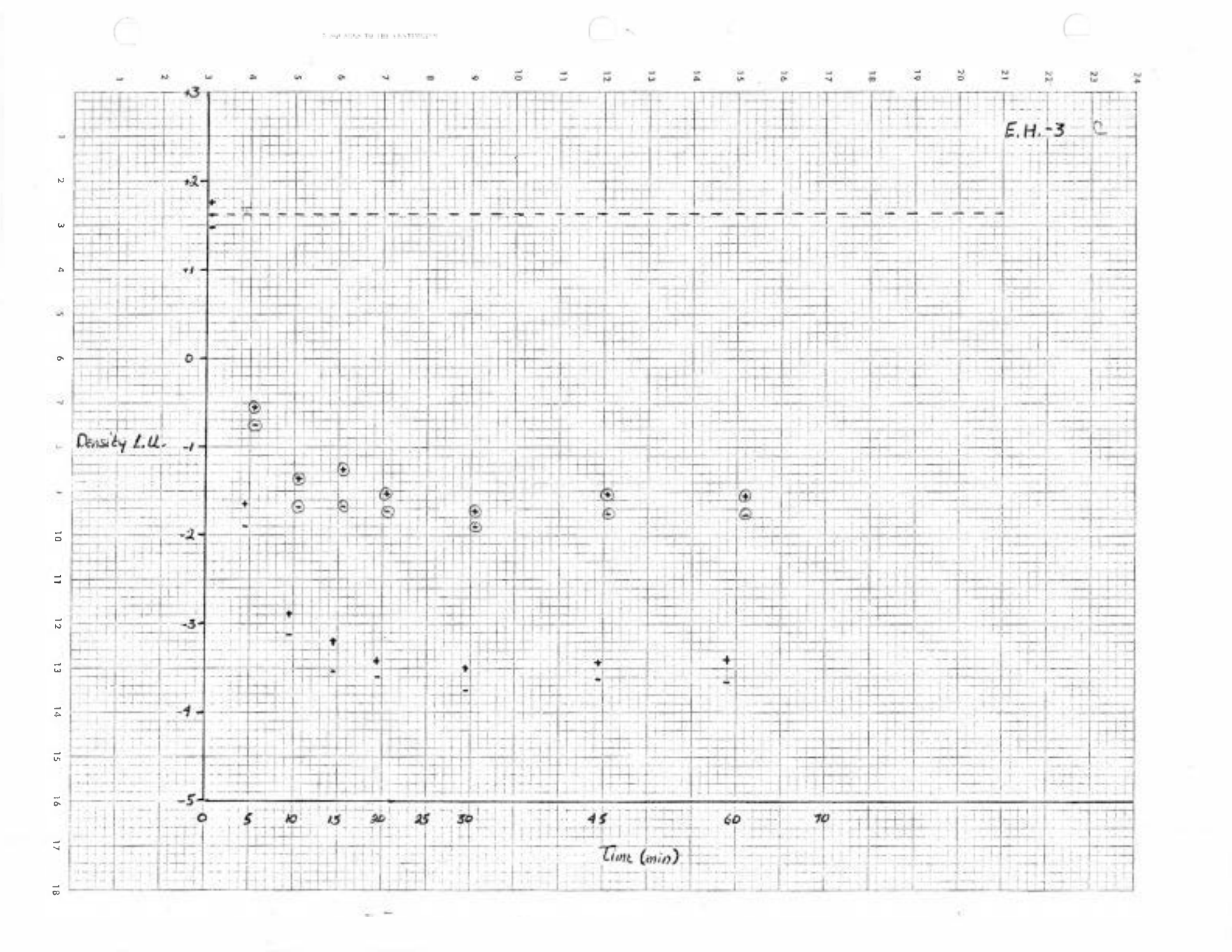
Fig. - 4
+3
+2
+1
0
-1
-2
-3
-4
-5
Density-LU
0
5
10
15
20
25
30
45
60
70
Time-(min)

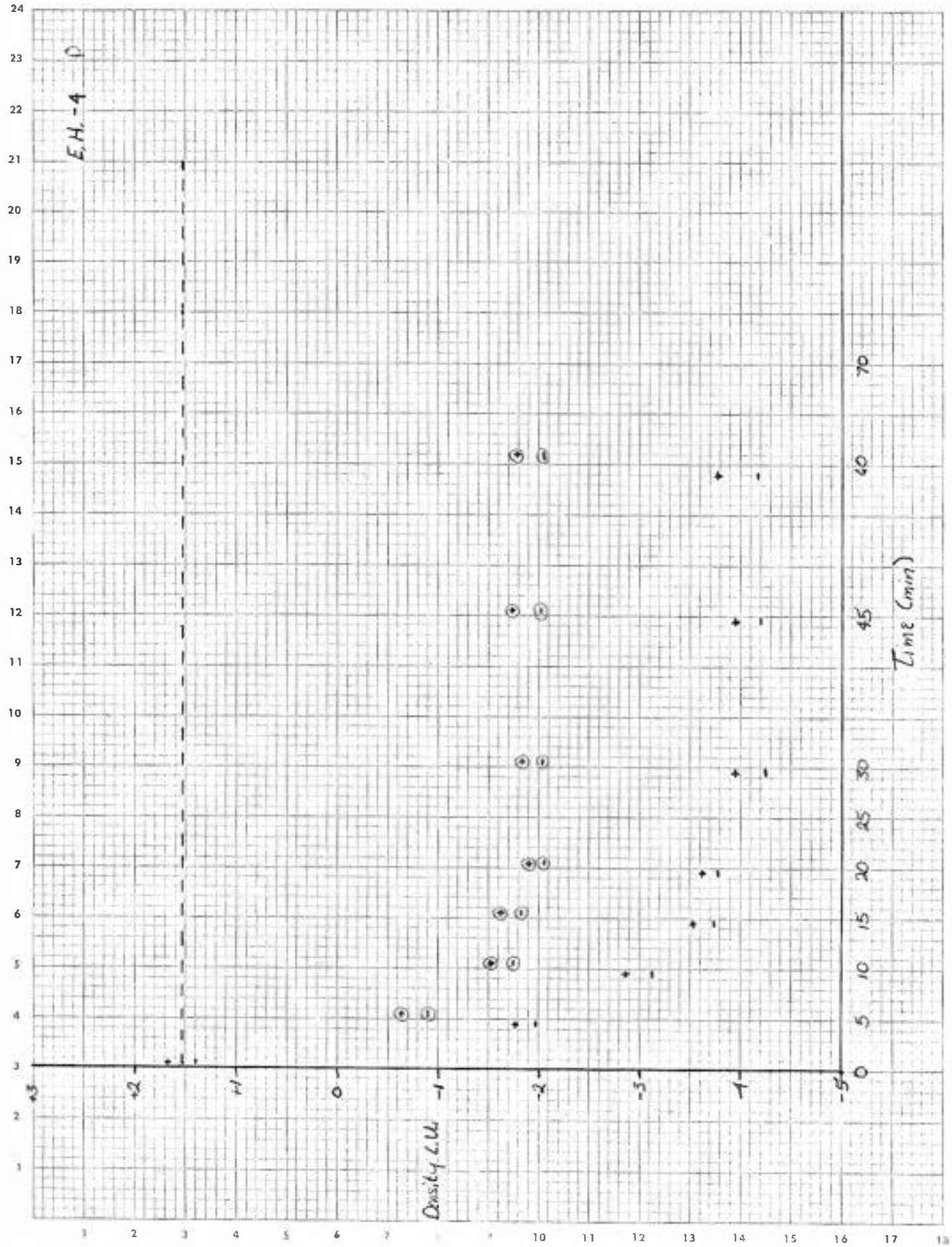

B.K.-5 C
+3
+2
+1
0
-1
-2
-3
-4
-5
Density-LU
0
5
10
15
20
25
30
45
60
70
Time-(min)

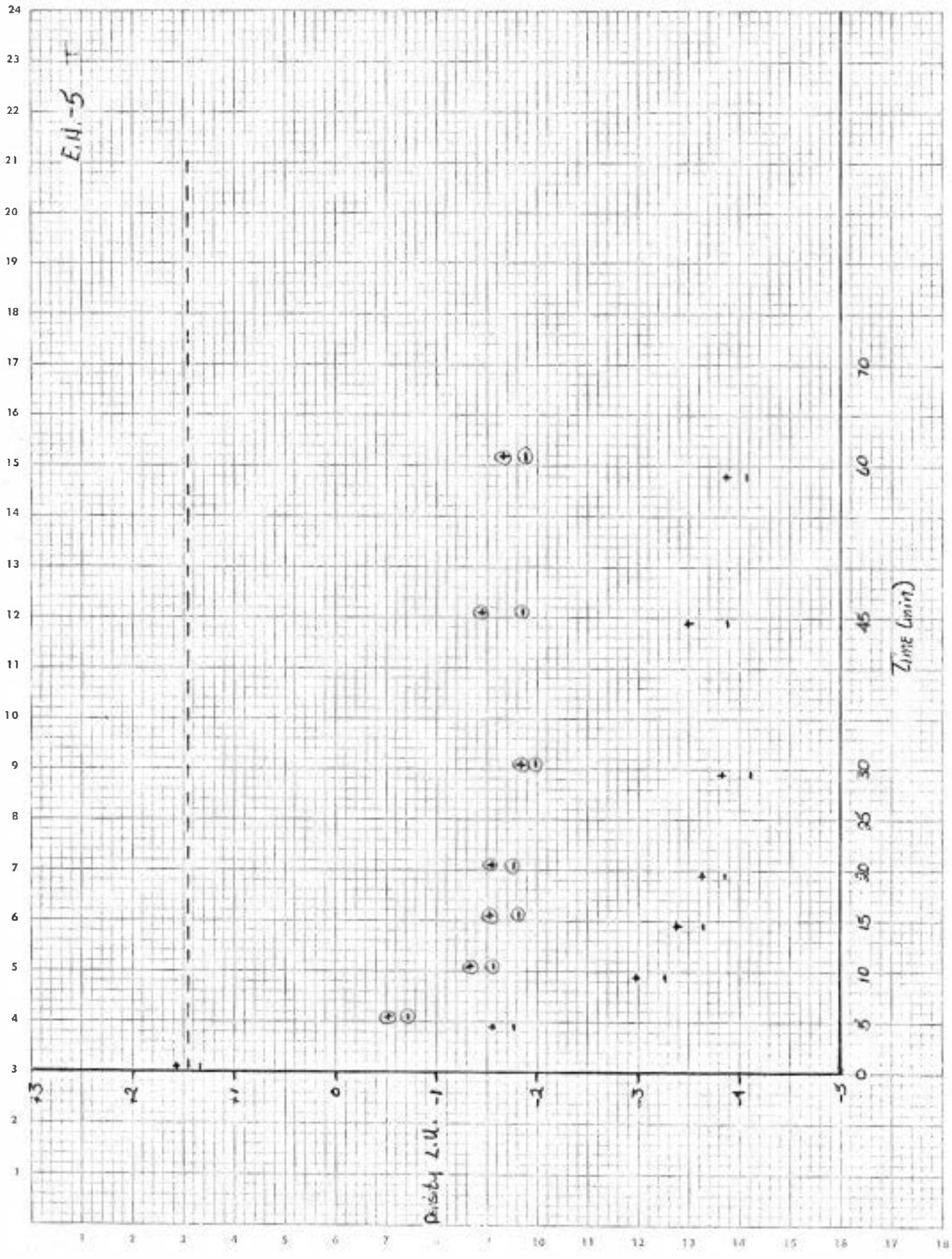

B.F.-6
Density-LL
Temp (°C)

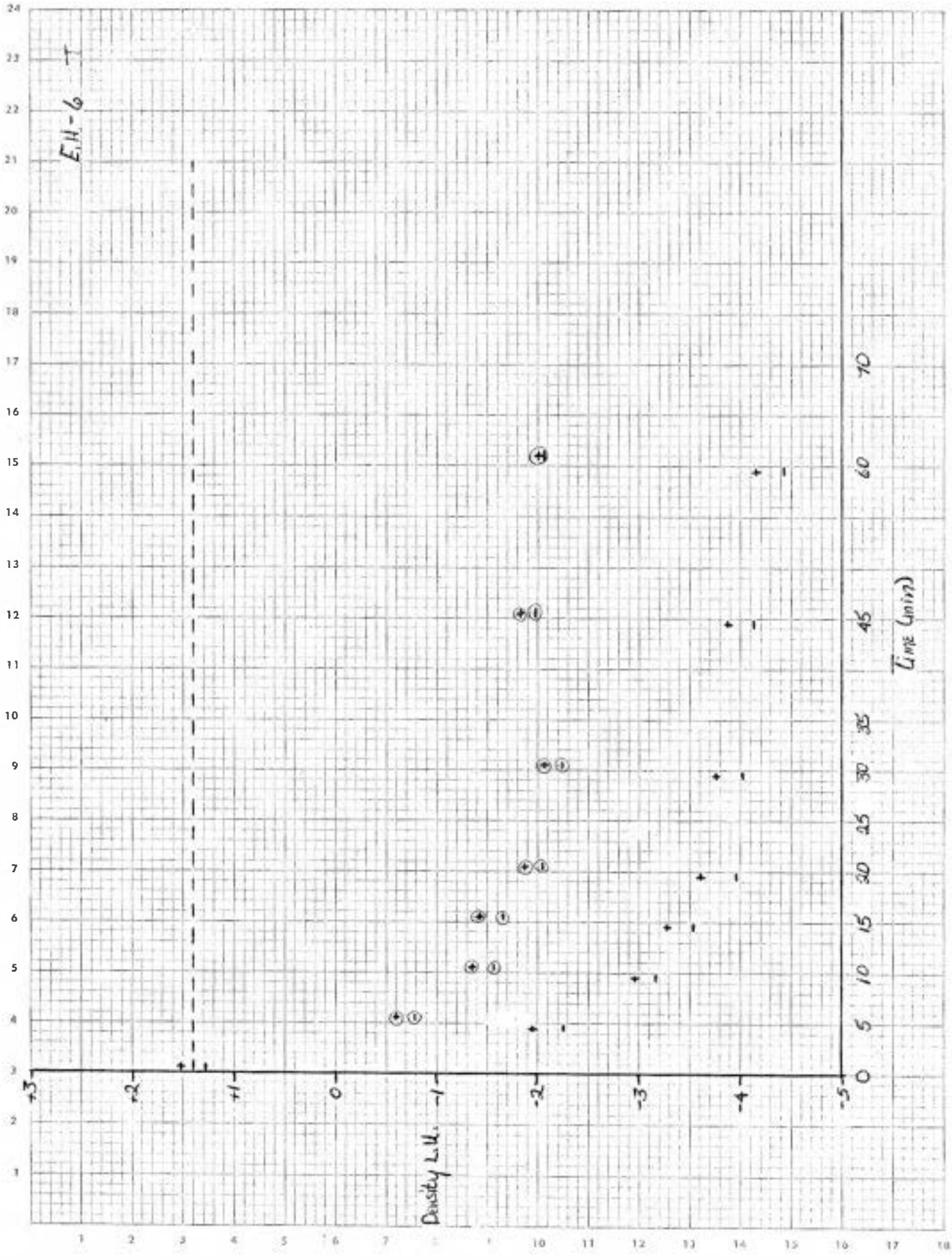

E.H.-2
Density L.U.
Time (min)
+3
+2
+1
0
-1
-2
-3
-4
-5
0
5
10
15
20
25
30
35
40
45
70


E.U. -2
+3
+2
+1
0
-1
-2
-3
-4
-5
Density L.U.
Time (min)
0
5
10
15
20
25
30
60
70


E.H.-3
+3
+2
+1
0
-1
-2
-3
-4
-5
Density L.U.
0
5
10
15
20
25
30
45
60
70
Time (min)


E.H.-4
Density (LU)
Time (min)


E.U.-5
Time (min)
Density E.U.


E.H-6
Density L.U.
+3
+2
+1
0
-1
-2
-3
-4
-5
Time (min)
0
5
10
15
20
25
30
35
40
45
50
55
60

APPENDIX D

Conversion of Filter Values to Log Units

CALIBRATION TABLES

Variable and Fixed Neutral Density Filters

Variable filter setting in mm.		Fixed #1	Fixed #1&#2	Fixed #1&#3	Fixed #1&#2&#3	Beam splitter
16	+2.714	+0.480	-1.808	-0.769	-3.057	+2.572
15	+2.607	+0.373	-1.915	-0.876	-3.164	+2.465
14	+2.452	+0.218	-2.070	-1.031	-3.319	+2.310
13	+2.297	+0.063	-2.225	-1.186	-3.474	+2.155
12	+2.143	-0.091	-2.379	-1.340	-3.628	+2.001
11	+1.991	-0.243	-2.531	-1.492	-3.780	+1.849
10	+1.845	-0.389	-2.677	-1.638	-3.926	+1.703
9	+1.695	-0.539	-2.827	-1.788	-4.076	+1.553
8	+1.548	-0.686	-2.974	-1.935	-4.223	+1.406
7	+1.405	-0.829	-3.117	-2.078	-4.366	+1.263
6	+1.255	-0.979	-3.267	-2.228	-4.516	+1.113
5	+1.114	-1.120	-3.408	-2.369	-4.657	+0.972
4	+0.964	-1.270	-3.558	-2.519	-4.807	+0.822
3	+0.813	-1.421	-3.709	-2.670	-4.958	+0.671
2	+0.663	-1.571	-3.859	-2.820	-5.108	+0.521
1	+0.505	-1.729	-4.017	-2.978	-5.266	+0.363
0	+0.342	-1.892	-4.180	-3.141	-5.429	+0.200

Fixed Neutral Density Filter Values:

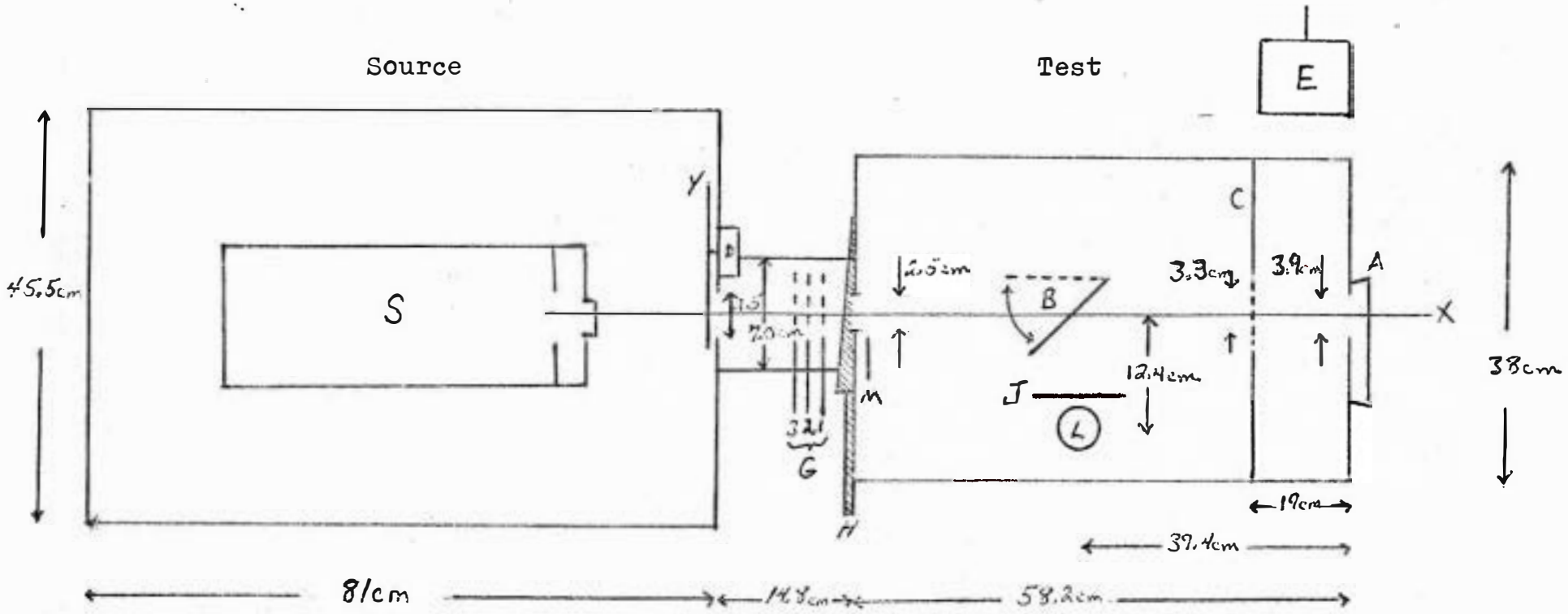
#1= +2.234 log units
#2= +2.288 log units
#3= +1.249 log units

Beam splitter:
+0.142 log units

APPENDIX E

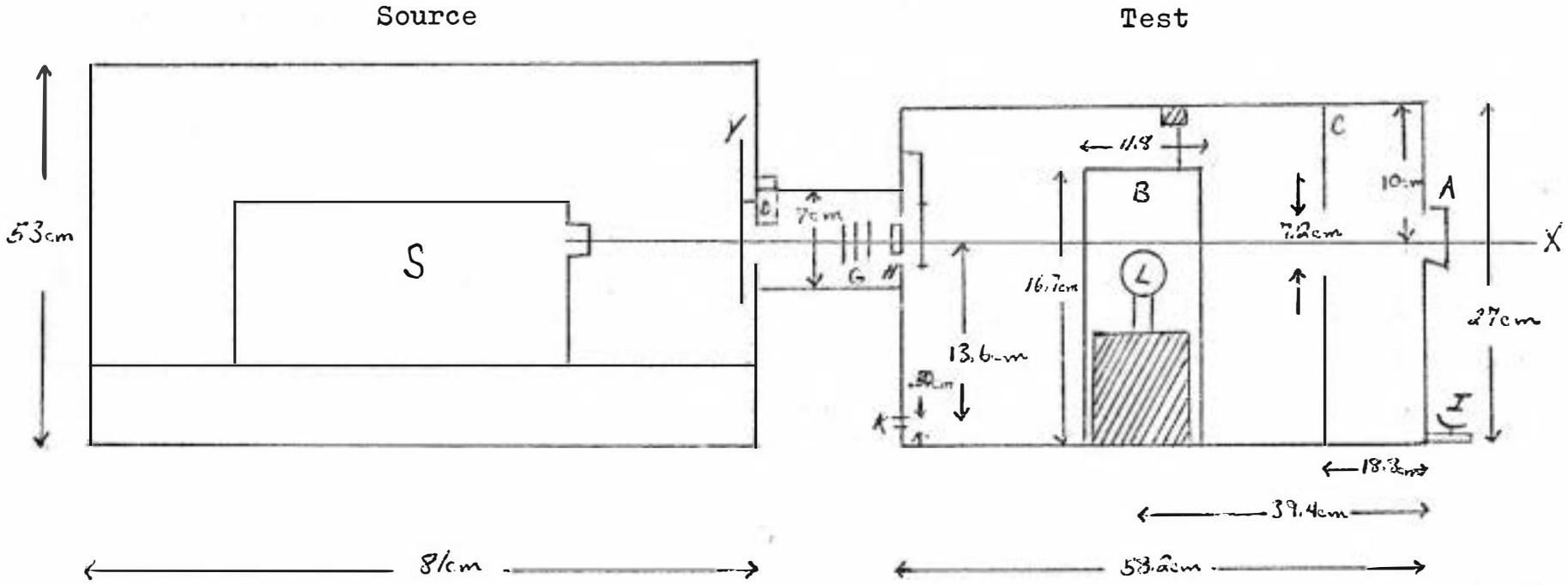
Apparatus

Schematic and Wiring Diagrams



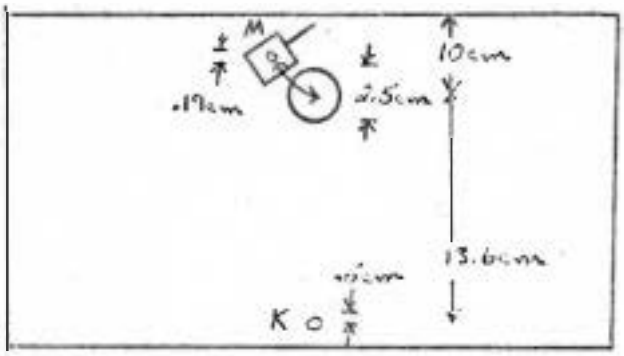
TOP VIEW

A- Rubber Eye Shield
B- Movable Beam Splitter
C- Aperatured Partition
D- Digimotor
E- Subject Control Switch
G- Movable Filters
H- Variable Density Wedge
L- 100w/110v Incandescent Light
M- Movable Small Stimulus
X-,Test Axis
Y- Shutter
K- Fixation Source

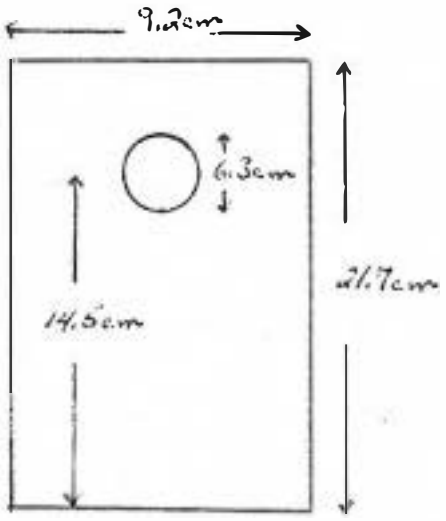


SIDE VIEW

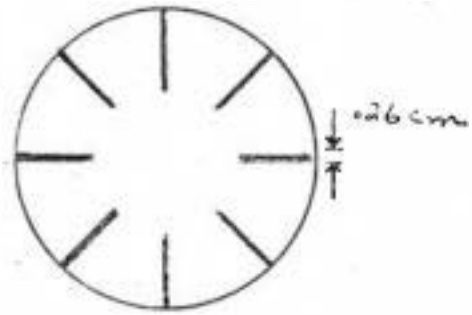
A- Rubber Eye Shield
B- Movable Beam Splitter
C- Aperatured Partition
D- Digimotor
G- Movable Filters
H- Variable Density Wedge
I- Adjustable Chin Rest
J- Shield for Pre-Adapt. Light (not shown)
K- Fixation Source
L- 100w/110v Incandescent Light
M- Movable Small Stimulus
X- Test Axis
Y- Shutter



End View Test Box (inside)

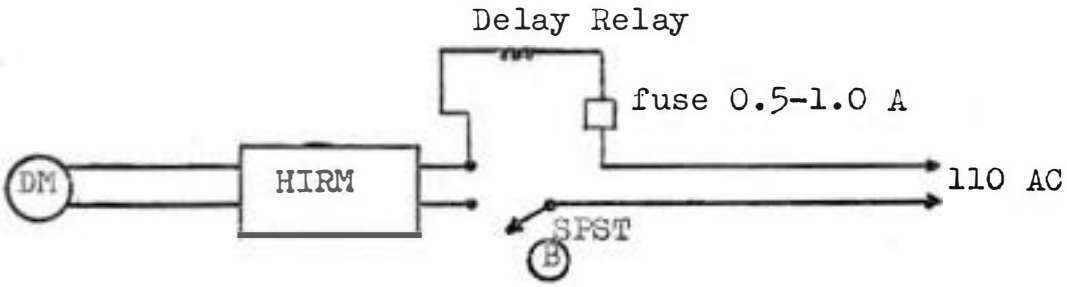


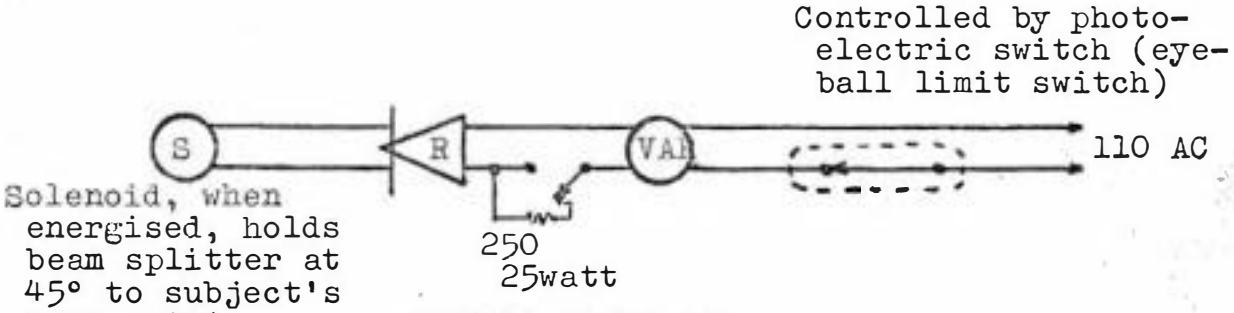
J (detail)

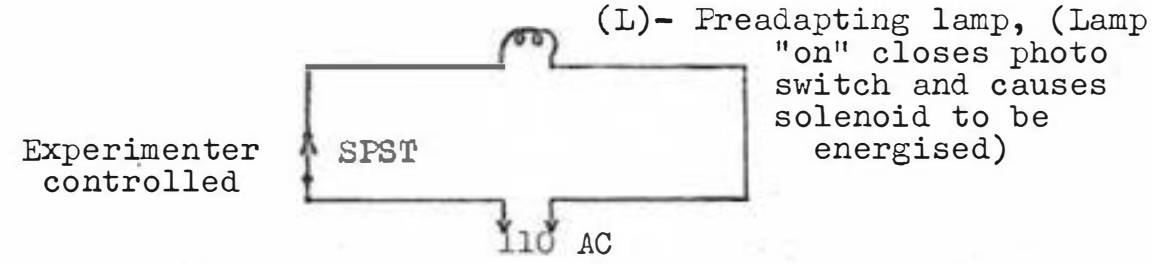


Shutter

Circuit Diagram







HIRM= Hold-in resistor module(including rectifier)
DM = Digimotor
R = Rectifier for solenoid
S = Solenoid
VAR = Variac (auto transformer set for output voltage that will supply 47 volts DC from rectifier)
A = Experimenter controlled switch
B = Subject controlled switch

* Test axis is line joining test patch to retinal area tested.

Circuit modifications were made to achieve the following:

1. Keep preadapting lamp on while subject operates shutter (digimotor).
2. Replace full reflector with beam splitter so that base line threshold can be determined before turing off preadapting lamp.

ORIGINAL DATA

(May be found with the original copy of this thesis on record at Pacific University Library)