



129
653
THS

AN EXPERIMENTAL STUDY OF THE
EARLY VOLUME CHANGE OF
VARIOUS CEMENT MORTARS

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE
C. R. Vigstedt
1947

THESIS

C.1

An Experimental Study of the Early
Volume Change of Various
Cement Mortars

A Thesis Submitted to

The Faculty of
MICHIGAN STATE COLLEGE
of
AGRICULTURE AND APPLIED SCIENCE

by

C. R. Vigstedt

Candidate for the Degree of

Bachelor of Science

June 1947

ACKNOWLEDGEMENT

The author wishes to thank Professor Allen and Mr. Hall of the Civil Engineering Department for their help and advice, and Mr. Finney and Mr. Rhodes of the Michigan State Highway Department for their guidance and cooperation.

Table of Contents

Introduction	1
Theory	2
Procedure	4
Photographs	101
Testing of Measuring Methods	11
Data	12
Conclusions	35

INTRODUCTION

The early volume change of concretes within the first ten hours of set has been causing cracks to occur in pavements and other concrete structures. In an experiment conducted by Mr. Wuerpel of the United States Army Engineers he found that the greatest expansion occurred during the first ten hours of set and that after this period the concrete contracted, sometimes to a volume less than the original placed volume. It is this contraction after the initial set which causes the contraction cracks.

Only two experiments are known to have been conducted in the accurate measurement of the volume change that occurs at this time. One was conducted by Mr. Wuerpel of the United States Army Engineers and was reported in the American Concrete Institute Journal for February, 1946. The other was conducted by the Dewey and Almy Chemical Company.

THEORY

The first necessary step in the study and possible rectification of the volume change of concretes is to devise an accurate method of measuring this volume change.

Instead of measuring a concrete mix, a cement mortar mix can be used. The reason for this substitution is that if the temperature of each part of the experiment is held constant there will be no volume change due to temperature changes; therefore a cement mortar mix can be substituted for a concrete mix and, after the volume change is measured, a correlation between these mixes can be calculated. This will give many advantages, such as: (1) the equipment involved can be simpler using a mortar mix, (2) the equipment can be smaller and more easily transported, (3) the mix designs for testing will be simpler, (4) the experimental factors to be controlled will be less, thus allowing more accurate results, and (5) more samples can be checked at the same time.

In using the foregoing theory, the cement mortar method was undertaken and the following factors were held constant: (1) the water-cement ratio was held at .4, (2) the consistency was held constant at fifty through a flow table check, (3) the temperature was held constant by placing the samples in a Constant Temperature Room or a Constant Temperature Bath, and (4) the length of time for the samples to be checked was selected as forty-eight hours with a twenty-four hour re-run check. Three samples of each mix design tested were run.

With the above physical factors held as constant as equipment will allow, the only factor to effect the volume will be the chemical reaction within the mix itself.

Based on the preceding theory, the following procedure was developed and used.

PROCEDURE

Loading Methods

A great deal of difficulty was experienced in finding a material in which a cement mortar could be placed and the volume change recorded over a forty-eight hour period. Balloons and other similar materials were tried but they proved to have either too small a volume or else they were too thin and broke when loaded. It was finally found that the balloons used by the Michigan State Highway Department for measuring the volumes of cores taken from pavements were suitable. These balloons were thick enough to resist tearing when loaded and were of sufficient volume to provide an adequate test sample.

In order that the balloon could be loaded without distending it, it was placed in a 500 ml graduate and the ends doubled back over the outside of the graduate. This left the balloon hanging inside the graduate with the end open for easy loading. After the material to be tested had been thoroughly mixed, loading was started. The balloon was filled one-fourth full and the material pushed down with the fingers until no air pockets could be seen. This was repeated until the balloon was filled to about one inch of the top with the mixture. Here a problem arose. When a string was tied around the balloon and it was placed into the apparatus for measurement, water would flow into the mixture causing erroneous readings.

The first method tried in sealing off the balloon was to insert a rubber stopper into the balloon tight against the mixture and secure it with a string tied around the outside of the balloon against the stopper sides. Although this proved satisfactory, it was abandoned in favor of wax. In the use of wax, the wax was poured into the loaded balloon to

about a one-fourth inch depth. A string was wrapped around the balloon at the point where the liquid wax was, pulled tight, and tied. The whole balloon was then immersed in water heated to experimental temperature in order to eliminate any possible expansion or contraction caused by the heat of the wax.

The above method was employed throughout the entire work.

Measuring the Volume Change

After the most satisfactory method of loading the balloons had been determined, the next step was to devise a way to measure accurately the volume change that was to occur.

The following contains an account of the methods attempted and in case of failure the reason or reasons for each failure.

Method One

This method was the one used by Wuerpel of the United States Army Engineers. The equipment used was: (1) a desiccator, eight inch diameter, with a hole suitable for containing a rubber stopper located in the removable top; (2) a number six rubber stopper; and (3) a twenty ml. burette.

The bottom and the top of the desiccator were carefully greased with stop cock grease at their junction to insure that no leakage would occur at this point. The bottom of the desiccator was filled with water that had been boiled to remove the extraneous air. The specimen to be measured was lowered into the water and suspended by means of an attached string that was run through the top of the desiccator. The top of the desiccator was then fitted onto the bottom and turned about half a revolution to insure a tight fit. The string attached to the specimen was then attached to the rubber stopper. The rest of the desiccator was filled with water until it overflowed the top. The rubber stopper was inserted into the top of the desiccator on a slant and then pushed firmly into the top. The twenty ml. burette was then filled with water to the ten ml. mark and inserted into the stopper. All materials used were carefully warmed to 74° F in order that any volume change due to

temperature changes would be eliminated. The entire apparatus was then placed in a Constant Temperature Room for observation.

This method proved unsatisfactory since the Constant Temperature Room proved impossible to accurately control at temperatures below room temperature.

The method was exactly repeated again except that the materials and apparatus were warmed to 78° F before starting. Twenty minutes were allowed, from the time the water was added to the mix until the first reading was taken, for chemical reaction to begin.

This second try also proved unsatisfactory. The Constant Temperature Room was much easier to control accurately at this higher temperature. However, all readings were inaccurate due to the relatively small volume change experienced and the large equipment used to measure this change.

Method Two

This method was used to decrease the size of equipment and to use more delicate equipment to measure this small volume change.

The equipment used was a wide neck bottle, a number eleven rubber stopper, and a five ml. pipette. A wire ring was attached to the bottom of the rubber stopper to fasten the suspended specimen to.

The bottle was filled to overflowing with boiled water. The specimen was then suspended in the bottle by means of a string, the string was attached to the ring in the stopper, and the stopper was inserted into the bottle. It was found that the best way to insert the stopper was on a slant so that the chance of trapping any air in the bottle would be at a minimum. The pipette was then filled to the three ml. mark with boiled water. The water in the pipette was allowed to run

out as the pipette was inserted into the stopper opening in order to eliminate again the chance of trapping any air in the bottle. As the stopper and pipette were forced into the bottle, the water was driven up in the pipette. After several tries, it was found that this procedure would place the water in the pipette at the 2.5 ml. mark. All apparatus and specimens were carefully heated to desired temperature before assembling and testing.

This method failed because the pressure head in the pipette had not been taken into account. This pressure head exerted a pressure on the bottom of the rubber stopper forcing it up and causing the water in the pipette to drop below recording levels. The pipettes were refilled with water but the results obtained were too unsatisfactory to record. The pressure head reaction was not discovered until Method Four had been tried.

Method Three

Method Three was just a variation of Method Two. The entire procedure explained in Method Two was exactly duplicated. After the stopper and pipette had been inserted, the seams were coated with wax. As soon as the wax had been applied, the entire apparatus was immersed in a vessel containing water heated to experimental temperatures to eliminate any expansion due to the wax heat. The apparatus was then placed in a Constant Temperature Bath and checked.

This method also proved unsuccessful due to rebound from the rubber stopper destroying the bond of the wax and the pressure caused by the head in the pipette.

Method Four

Method Four was a variation of Methods Two and Three. The entire procedure described in Method Two was repeated again with the following variation. The rubber stopper edges and the pipette sides were heavily coated with stop cock grease before final assembly of the apparatus.

This method also failed. Although at this point the rubber stopper rebound had been eliminated, there was still the pressure head in the pipette to consider. It must be remembered that, although the pressure head has been mentioned previously to this, it was not discovered until this point.

Method Five

Method Five is a variation of Method Four.

The procedure was an exact duplication of Method Four. However, when the stopper was placed on the bottle, it was wired down by means of a wire looped around the bottle neck and looped over the stopper diametrically.

This method also failed for two reasons. The first was that the wire looped around the bottle neck did not provide much to hold to and slipped off easily. Secondly, the wire caused deformation of the stopper and allowed air to leak into the bottle.

Another variation of this method was tried by looping two wires 90° apart diametrically over the rubber stopper, but both difficulties previously described were encountered again.

Method Six

Method Six was a duplication of Method Four until completion. At this point wood clamps were fixed to the bottle by means of three eight inch carriage bolts and tightened securely.

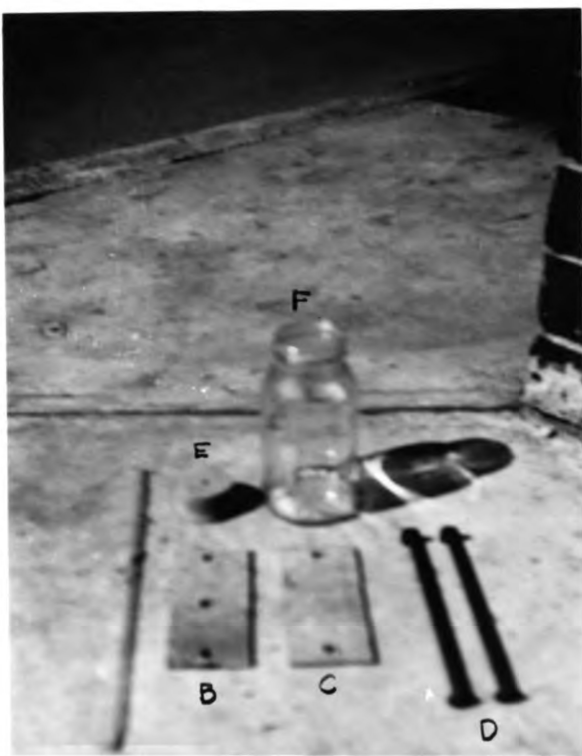
Had it been possible to use the Constant Temperature Room, this method would have proved satisfactory. However, the immersion of the wood into the Constant Temperature Bath caused it to swell, and inaccurate results were obtained.

Method Seven

Method Seven was the final method attempted and it proved satisfactory. Here metal strips were substituted for the wood end pieces and two eight inch carriage bolts were used. This method proved satisfactory because it stopped entirely the rubber stopper rebound and held the stopper from being pushed up by the pressure head. When proven satisfactory, this method was used throughout the rest of the study.

METHOD SEVEN - APPARATUS

- | | |
|--------------------------|-------------------|
| A- 5ml Pipette | D- Carriage Bolts |
| B- Top Pressure Plate | E- Rubber Stopper |
| C- Bottom Pressure Plate | F- Bottle |



A



D

F

D

C

TESTING OF MEASURING METHODS

All methods were tested by filling the apparatus with boiled water, omitting the placing of the material to be tested in the apparatus, and then placing it in the Constant Temperature Bath for a twenty-four hour period. If no variation from the original reading, except for evaporation which was recorded by the evaporation standard, was recorded, the method was then accepted as satisfactory and used.

DATA

The following data were observed and recorded. It will be noticed that there has been no correction for temperature rise, but that it has been noted on the graphs. This has been done at the request of the Michigan State Highway Department since no accurate correction could be made for the expansion of the mortar itself.

PORTLAND CEMENT

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:

CEMENT 250g
WATER 100g
SAND 425g
TOTAL 775g

WATER-CEMENT RATIO - .4
% WATER - 12.9%
FLOW TABLE - 50

DATA

TIME	HOURS	TEMP	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1600											
1645	0	76°	2.45	2.27	2.63	0	0	0	0	0	0
0815	.75	76°	2.60	2.34	2.77	.15	.07	.06	.12	.07	.06
1000	16.25	77.5°	4.22	4.03	4.25	1.77	1.76	1.58	1.42	1.69	1.48
1200	18.00	76.5°	0.60	0.40	0.66	1.96	1.96	1.72	1.57	1.88	1.61
1405	20.00	76°	0.76	0.60	0.91	2.12	2.16	1.97	1.73	2.08	1.84
1438	22.08	81°	0.40	0.23	0.38	1.79	1.79	1.44	1.41	1.72	1.35
1650	22.63	81°	0.40	0.23	0.40	1.76	1.79	1.46	1.41	1.72	1.36
1800	24.80	77°	0.72	0.62	0.73	2.08	2.18	1.79	1.67	2.10	1.68
1250	26.00	76.5°	0.83	0.73	0.83	2.19	2.29	1.89	1.76	2.20	1.77
1430	44.80	73.5°	1.40	1.60	1.41	2.76	3.16	2.47	2.22	3.04	2.31
1541	46.50	73°	1.47	1.68	1.57	2.83	3.24	2.57	2.27	3.12	2.40
1655	47.66	75°	1.30	1.50	1.30	2.66	3.06	2.36	2.14	2.94	2.20
	48.90	76°	1.30	1.61	1.30	2.66	3.17	2.36	2.14	3.05	2.20

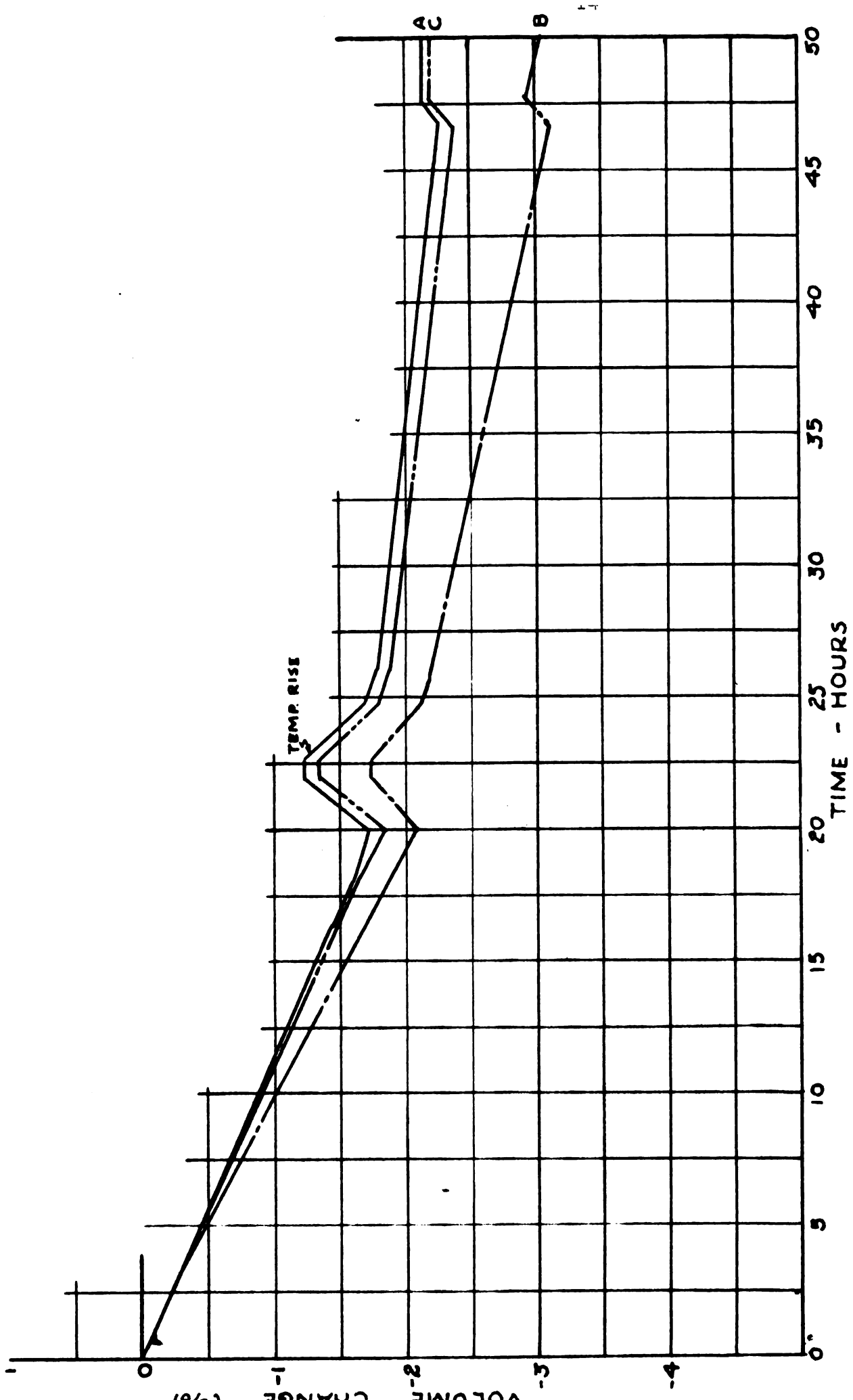
WATER ADDED 0.41 0.20 0.52

A WT AIR - 270.6
" WATER - 145.36
DIFF. - 124.76
VOL. 124.7 ML.

B WT " - 226.0
" WATER - 122.16
DIFF. - 103.96
VOL. 103.9 ML.

C WT AIR 239.6
" WATER 131.26
DIFF. 106.86
VOL. 106.8 ML.

PORTLAND CEMENT - 48 HR



VINSOL RESIN

DENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:

CEMENT 250 G
WATER 100 G
SAND 515 G
VINSOL RESIN 0256
TOTAL 865.0256

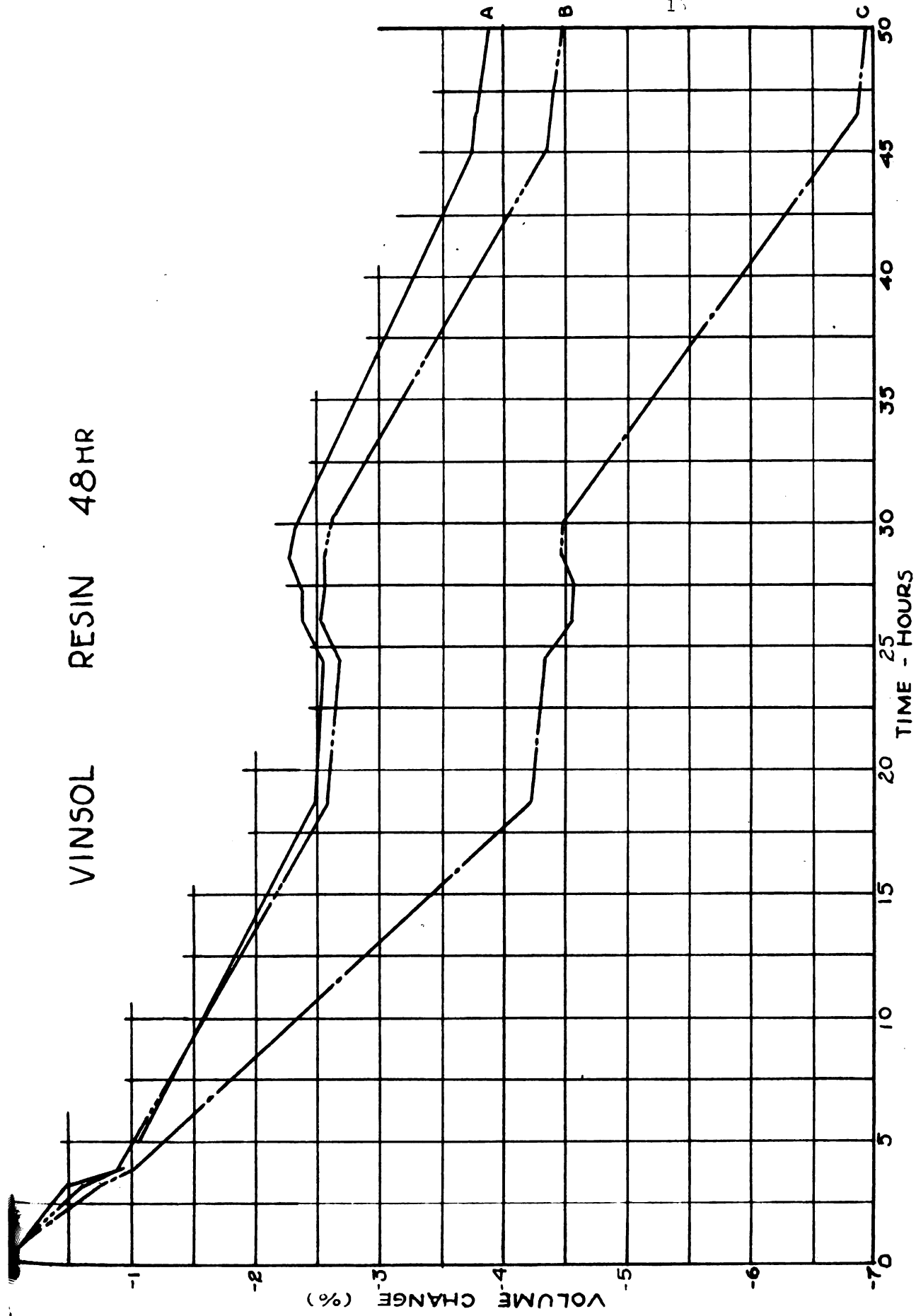
WATER-CEMENT RATIO - .4
FLOW TABLE - 50

DATA

TIME	HOURS	TEMP	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1405	0	81°	2.74	2.23	1.88	0	0	0	0	0	0
1438	.55	81°	2.78	2.21	1.90	.04	.02	.02	.04	.02	.02
1650	2.75	77°	3.30	2.92	2.54	.56	.69	.66	.50	.62	.79
1800	3.92	76.5°	3.82	3.23	2.75	1.08	1.00	.87	.96	.90	1.04
1850	4.83	73.5°	1.42	1.30	1.95	2.80	2.90	3.52	2.48	2.59	4.21
1930	24.42	73.0°	1.50	1.40	2.05	2.88	3.00	3.62	2.54	2.68	4.34
1941	26.02	75.0°	1.31	1.23	1.88	2.69	2.83	3.79	2.38	2.52	4.54
1953	27.27	76.0°	1.31	1.25	1.90	2.69	2.85	3.81	2.38	2.55	4.56
1827	28.82	78.0°	1.20	1.25	1.80	2.58	2.85	3.71	2.28	2.55	4.44
1933	29.90	77.0°	1.25	1.30	1.80	2.63	2.90	3.71	2.32	2.59	4.44
1038	44.98	72.5°	1.27	1.40	1.15	4.20	4.86	5.56	3.72	4.34	6.65
1219	46.64	72.0°	1.31	1.43	1.31	4.27	4.93	5.72	3.78	4.40	6.85
2032	53.10	72.5°	1.30	1.60	1.40	4.44	5.10	5.81	3.93	4.55	6.95
2200	54.56	72.5°	1.32	1.63	1.43	4.47	5.13	5.84	3.96	4.58	7.00

*ADD WATER -50 -60 -70
" " 0.43 0.42 0.35

A	WT	AIR	242.6	B	WT	AIR	245.6	C	WT	AIR	179.6
"	"	WATER	129.26	"	"	WATER	132.98	"	"	WATER	95.46
"	"	DIFF.	112.86	"	"	DIFF.	112.16	"	"	DIFF.	83.66
"	"	VOL.	112.8 CC	"	"	VOL.	112.1 CC	"	"	VOL.	83.66



FLY ASH

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTING:

CEMENT 250G
WATER 133G
SAND 602G
FLY ASH 83G

WATER - CEMENT RATIO - .4
FLOW TABLE - 50

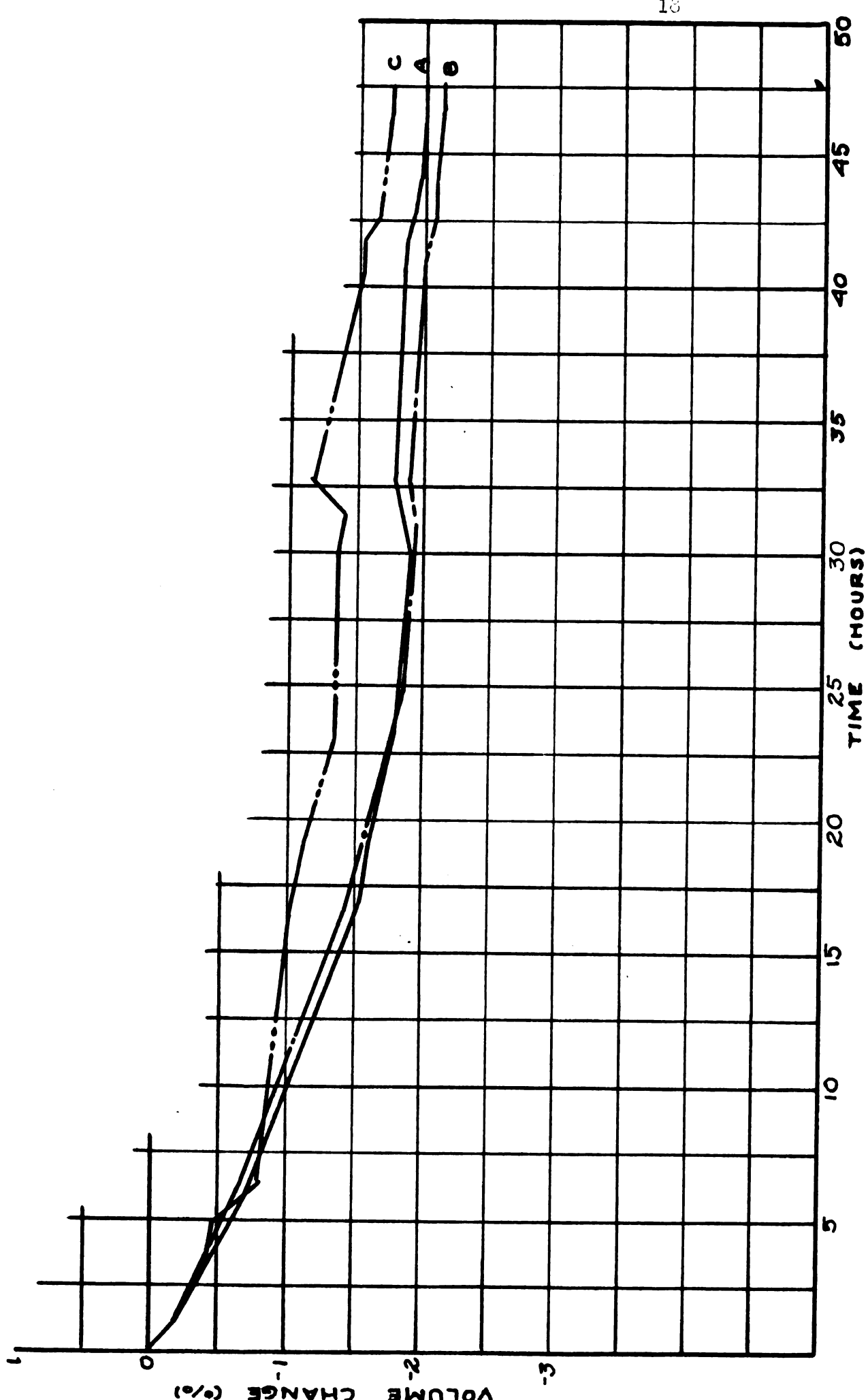
DATA

TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1550	0	74.0	1.15	1.18	1.54	0	0	0	0	0	0
1640	.83	74.5	1.34	1.42	1.83	.19	.24	.19	.17	.16	.15
1920	3.50	74.0	1.65	1.75	2.18	.50	.57	.54	.46	.37	.43
2045	4.92	74.0	1.80	2.00	2.40	.65	.82	.76	.59	.53	.49
2205	6.25	74.0	1.95	2.22	2.60	.80	1.04	.96	.73	.68	.79
0800	16.59	73.5	2.80	3.38	3.92	1.65	2.20	1.28	1.57	1.43	1.03
0930	17.83	73.5	2.85	3.48	4.02	1.70	2.50	1.58	1.55	1.49	1.09
1050	19.16	73.5	2.90	3.57	4.10	1.75	2.41	1.46	1.60	1.57	1.16
1330	21.82	73.0	3.03	3.74	4.27	1.88	2.58	1.63	1.73	1.68	1.29
1430	22.82	73.0	0.02	.86	0.50	1.90	2.62	1.67	1.74	1.70	1.32
1630	24.82	73.0	0.06	.68	0.52	1.94	2.80	1.69	1.77	1.82	1.34
2130	29.82	73.0	0.20	.50	0.53	2.08	2.98	1.70	1.90	1.94	1.35
2300	31.52	72.5	0.11	.50	0.60	1.99	2.98	1.77	1.82	1.94	1.40
0042	32.65	74.0	.20	.70	0.30	1.68	2.78	1.47	1.53	1.80	1.17
0835	40.65	74.5	0.13	.40	0.73	2.01	3.08	1.90	1.84	2.00	1.51
0930	41.65	74.5	0.15	.35	0.77	2.03	3.13	1.94	1.85	2.03	1.54
1018	42.45	74.0	0.20	.30	0.90	2.08	3.18	2.07	1.90	2.06	1.64
1145	43.93	74.0	0.25	.30	0.96	2.13	3.18	2.13	1.94	2.06	1.69
1405	46.26	74.0	0.30	.23	1.02	2.18	3.25	2.19	1.99	2.11	1.74
1515	47.58	74.0	0.30	.20	1.04	2.18	3.28	2.21	1.99	2.13	1.75

*ADD WATER 0 -90 4.46

A VOL 109.5 CC B VOL. 152 CC C VOL. 126.1 CC

FLY ASH



HYDROPEL

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:

CEMENT 2506
WATER 1006
HYDROPEL .0256
SAND 5956

WATER - CEMENT RATIO - .4
HYDROPEL 1 1/2 GALS. / SAND CEMENT
FLOW TABLE - 50

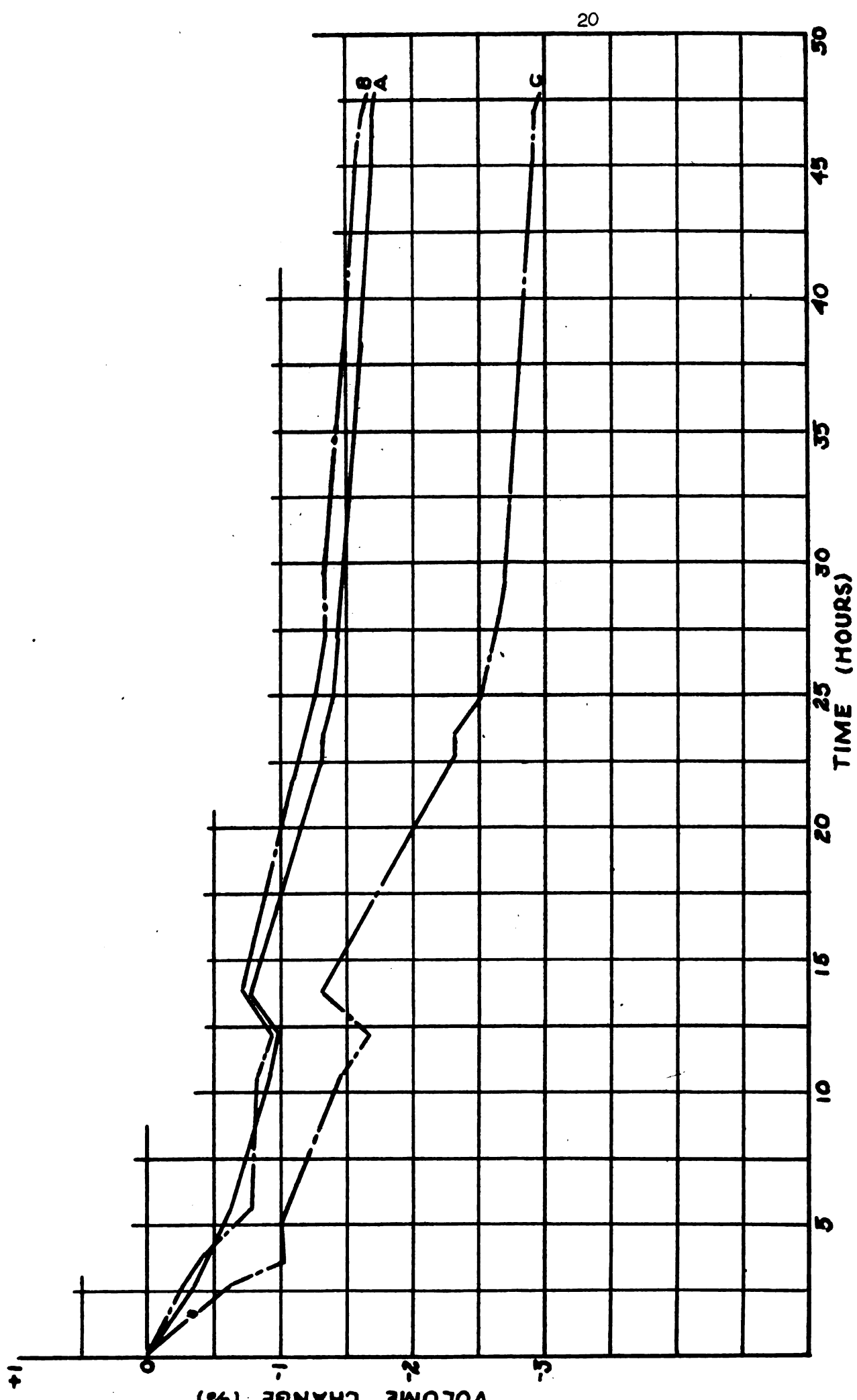
DATA

TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1050	0	73.5	0.72	0.80	0.83	0	0	0	0	0	0
1330	2.66	73.0	1.35	1.60	1.42	0.63	0.80	0.59	0.36	0.50	0.63
1430	3.66	73.0	1.40	1.84	1.78	0.76	1.04	0.95	0.44	0.65	1.02
1630	5.66	73.0	1.80	2.04	1.83	1.08	1.24	1.00	0.62	0.78	1.07
2130	10.66	73.0	2.15	2.21	2.19	1.43	1.41	1.36	0.82	0.83	1.46
2300	12.16	72.5	2.26	2.29	2.31	1.54	1.49	1.48	0.88	0.93	1.58
0042	13.82	74.0	2.05	1.95	2.05	1.33	1.15	1.22	0.76	0.72	1.31
0835	21.71	74.5	1.10	0.98	1.35	2.22	1.76	2.09	1.26	1.10	2.24
0930	22.63	74.5	1.20	1.05	1.42	2.32	1.86	2.16	1.32	1.16	2.31
1018	23.43	74.0	1.20	1.10	1.42	2.32	1.91	2.16	1.32	1.19	2.31
1145	24.87	74.0	1.34	1.20	1.62	2.46	2.01	2.36	1.40	1.25	2.53
1405	27.20	74.0	1.42	1.80	1.73	2.54	2.11	2.45	1.44	1.82	2.62
1515	28.36	74.0	1.46	1.33	1.80	2.58	2.14	2.52	1.48	1.34	2.70
2250	35.94	73.5	1.60	1.50	1.90	2.72	2.31	2.62	1.56	1.45	2.80
0805	45.19	74.0	1.74	1.74	2.00	2.96	2.54	2.72	1.70	1.59	2.92
0918	46.39	73.5	1.76	1.80	2.03	2.98	2.60	2.75	1.71	1.62	2.94
1026	47.60	73.0	1.80	1.86	2.05	3.02	2.66	2.77	1.73	1.66	2.97

* ADD WATER 0.21 0.34 0.48

A	WT	AIR	359 g	B	WT	AIR	331 g	C	WT	AIR	182.56
"	"	WATER	185.46	"	"	WATER	171.26	"	"	WATER	99.6
"	"	DIFF	173.66	"	"	DIFF.	159.86	"	"	DIFF.	98.56
"	"	VOL.	173.6 CC	"	"	VOL.	159.8 CC	"	"	VOL.	93.5 CC

HYDROPEL



IRON BOND

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:

CEMENT 250g
IRON BOND 13.3g
SAND 417g
WATER 100g

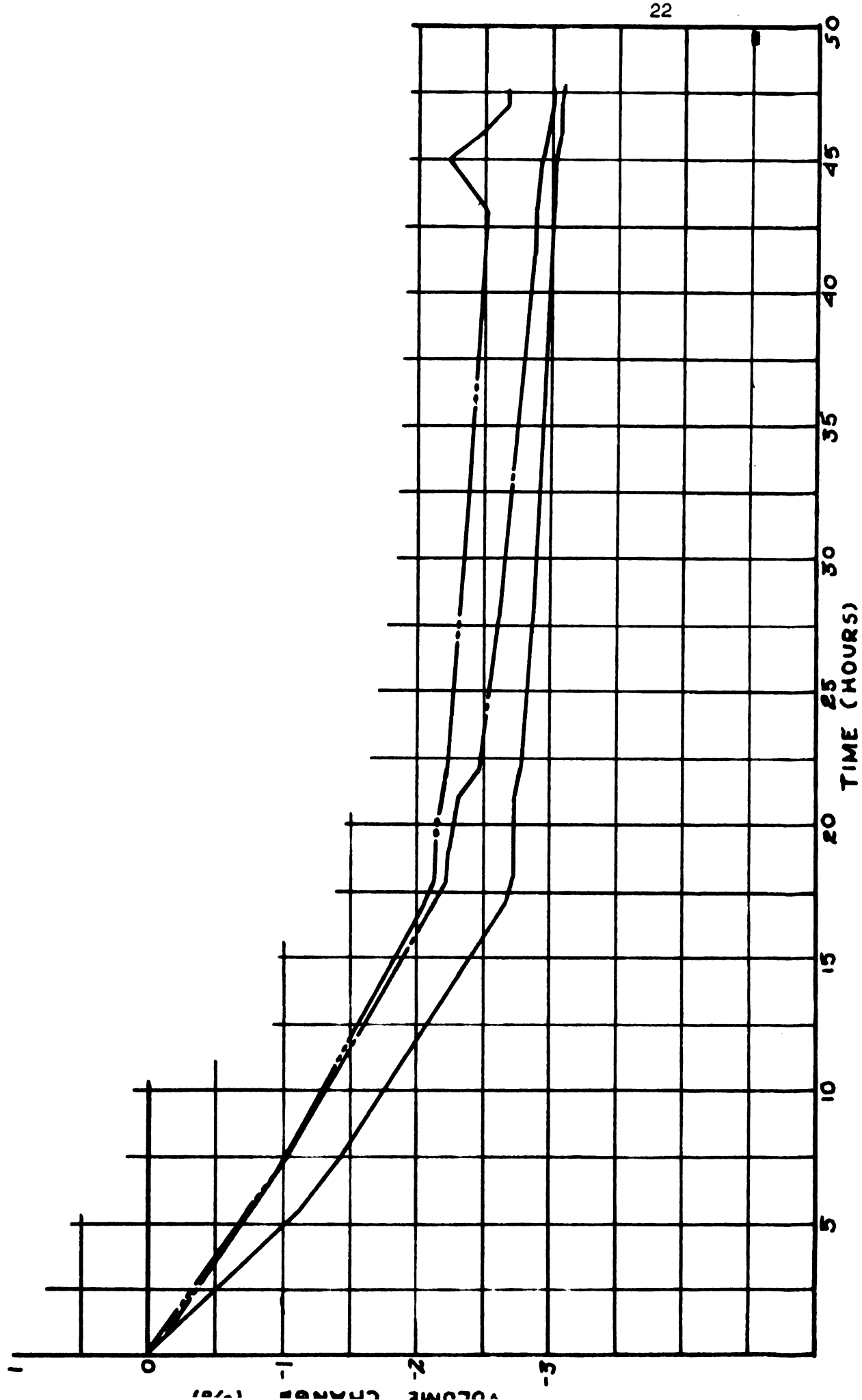
WATER - CEMENT RATIO - .4
FLOW TABLE - 50

DATA

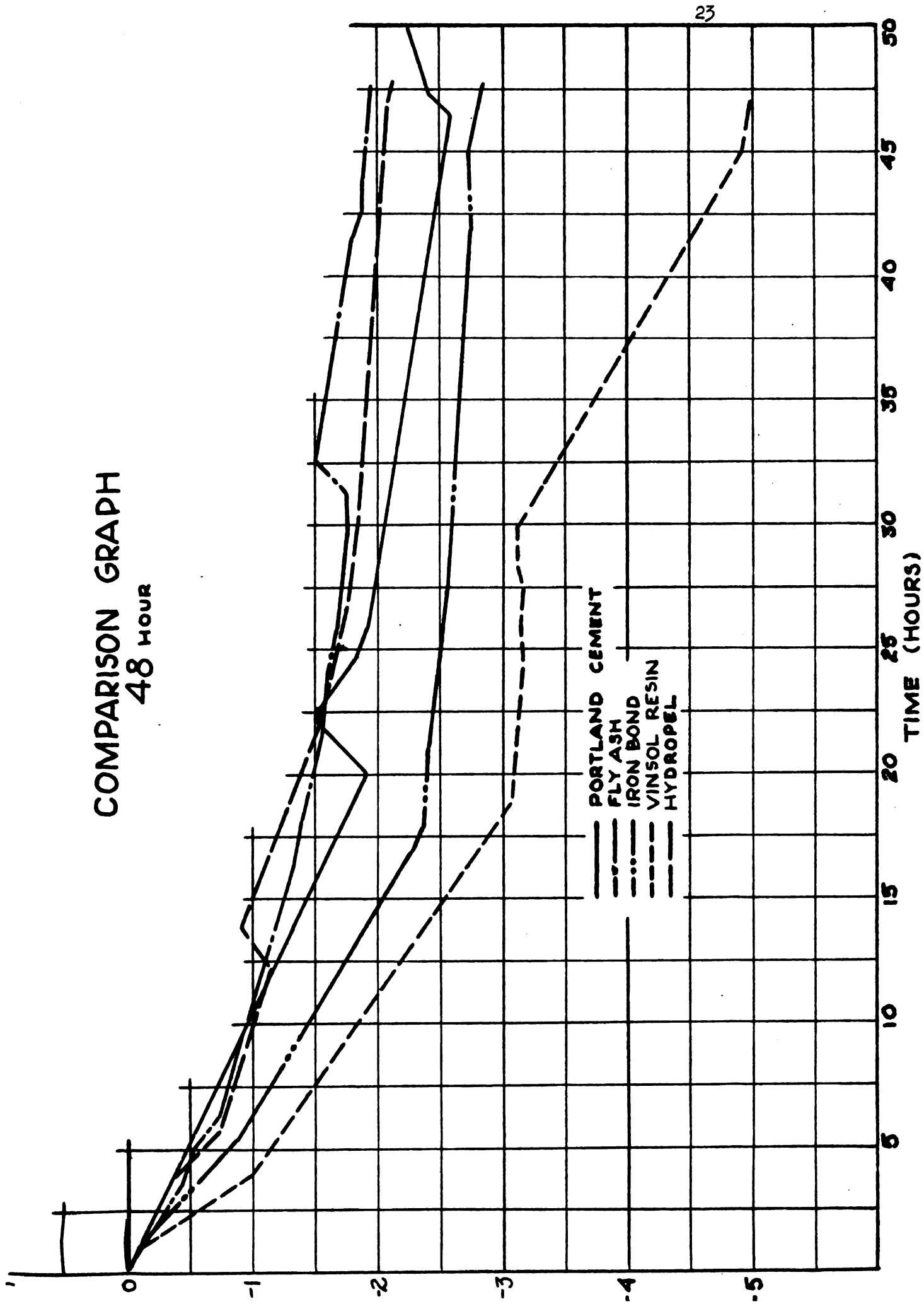
TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1600	0	73.5	-0.10	0.12	0.35	0	0	0	0	0	0
1700	1.00	73.5	0.12	0.26	0.51	.22	.14	.16	.20	.12	.17
2130	5.50	74.0	1.15	0.94	1.10	1.25	.82	.75	1.13	.72	.78
2245	6.75	73.5	1.35	1.16	1.24	1.45	1.04	.89	1.31	.91	.93
2330	7.50	74.0	1.48	1.31	1.33	1.58	1.19	.98	1.43	1.04	1.02
0900	17.00	73.5	2.85	2.57	2.32	2.95	2.45	1.97	2.66	2.14	2.05
1000	18.00	73.5	2.92	2.65	2.40	3.02	2.53	2.05	2.73	2.22	2.14
1100	19.00	73.5	2.93	2.67	2.40	3.03	2.55	2.05	2.74	2.24	2.14
1300	21.00	73.5	2.94	2.77	2.45	3.04	2.65	2.10	2.74	2.32	2.19
1400	22.00	73.5	2.98	2.94	2.48	3.08	2.82	2.13	2.78	2.47	2.22
1930	27.50	73.0	3.08	3.10	2.58	3.18	2.98	2.23	2.87	2.61	2.32
1000	42.00	74.0	3.22	3.40	2.76	3.32	3.28	2.41	3.00	2.88	2.57
1100	43.00	74.0	3.23	3.40	2.76	3.33	3.28	2.41	3.01	2.88	2.57
1300	45.00	74.0	3.26	3.46	2.48	3.36	3.34	2.13	3.03	2.93	2.22
1400	46.00	74.0	3.30	3.52	2.73	3.40	3.40	2.58	3.08	2.99	2.48
1500	47.00	74.0	3.30	3.53	2.90	3.40	3.43	2.55	3.08	3.01	2.66
1545	47.75	74.0	3.33	3.54	2.90	3.43	3.44	2.55	3.10	3.02	2.66

A VOL. 110.8 cc B VOL. 113.5 cc C VOL. 96.4 cc

IRON BOND



COMPARISON GRAPH 48 HOUR



PORTLAND CEMENT 24 HOUR

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:
CEMENT 250g
WATER 100g
SAND 425g

WATER-CEMENT RATIO - .4
FLOW TABLE - 50

DATA

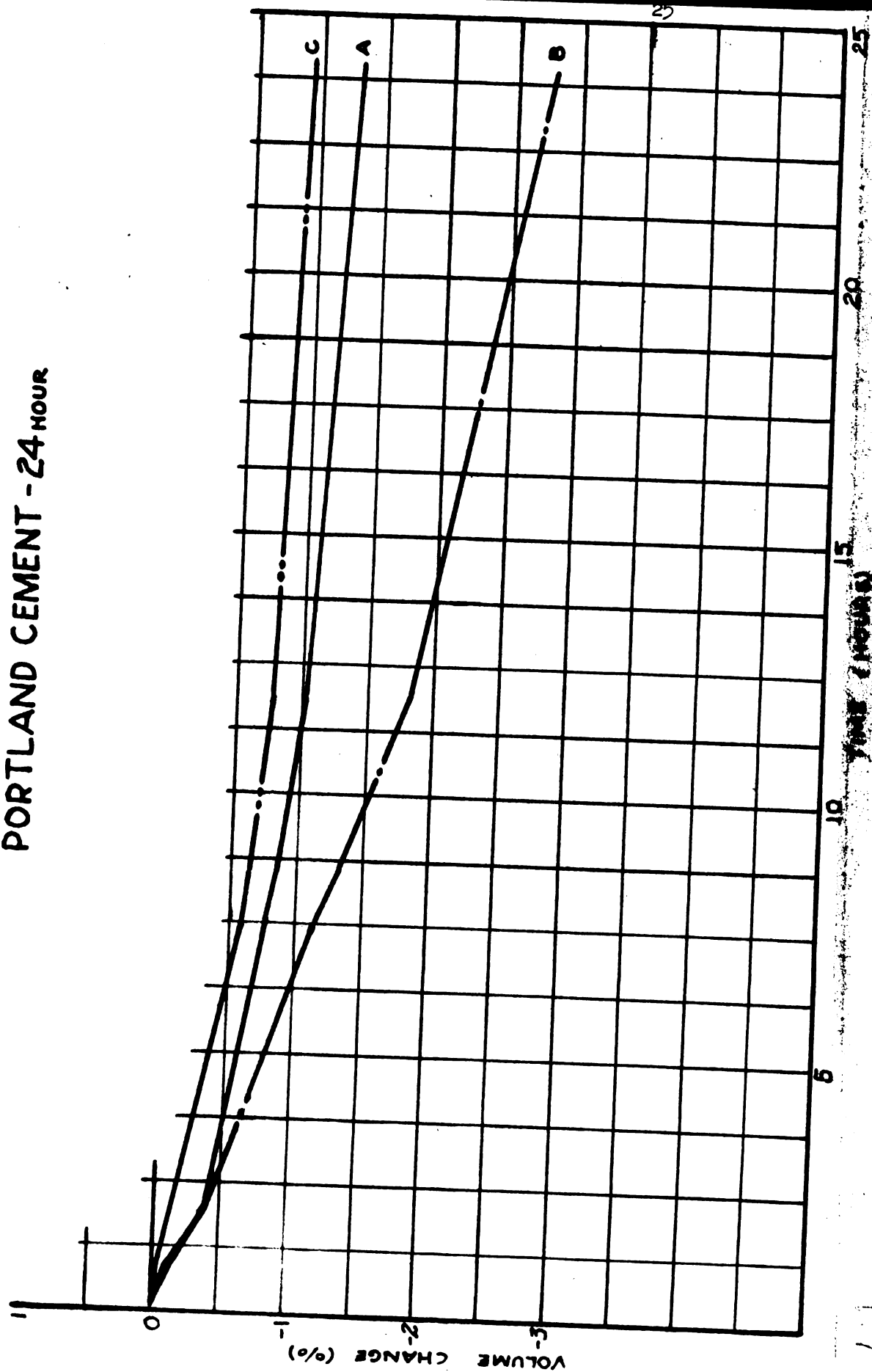
TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
0930	0	73.5	0.67	1.08	0.54	0	0	0	0	0	0
1020	.83	73.5	0.97	1.32	0.60	.30	.24	.06	.24	.22	.05
1120	1.83	73.5	1.12	1.48	0.70	.45	.40	.16	.36	.38	.13
1155	2.42	73.5	1.18	1.55	0.75	.51	.47	.21	.41	.45	.17
1250	3.33	73.5	1.28	1.69	0.85	.61	.61	.31	.49	.59	.24
1330	4.00	73.5	1.33	1.77	0.91	.66	.69	.37	.53	.66	.29
1400	4.50	73.5	1.38	1.84	0.98	.71	.76	.44	.57	.73	.35
1430	5.00	73.5	1.43	1.90	1.02	.76	.82	.48	.61	.79	.38
1500	5.50	73.5	1.46	1.96	1.08	.79	.88	.54	.64	.85	.43
1530	6.00	73.5	1.51	2.05	1.13	.84	.97	.59	.68	.93	.46
1600	6.50	73.5	1.56	2.13	1.20	.89	1.05	.66	.73	1.01	.52
1630	7.00	73.5	1.60	2.20	1.26	.93	1.12	.72	.75	1.08	.57
1700	7.50	73.5	1.64	2.28	1.30	.97	1.20	.76	.78	1.15	.60
1800	8.50	73.5	1.74	2.44	1.36	1.07	1.36	.82	.86	1.31	.65
2120	11.83	73.5	1.96	2.98	1.52	1.29	1.90	.98	1.04	1.83	.77
0930	24.00	73.5	2.30	4.02	1.75	1.63	2.94	1.21	1.31	2.81	.95

A VOL. 124.1cc

B VOL. 103.7cc

C VOL. 127.1cc

PORTLAND CEMENT - 24 HOUR



VINSOL RESIN - 24 HOUR

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING

CEMENT 250 G
WATER 100 G
SAND 515 G
VINSOL RESIN .025 G

WATER - CEMENT RATIO - .4
FLOW TABLE - 50

DATA

TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1330	0	73.5	0.75	1.14	0.62	0	0	0	0	0	0
1400	.50	73.5	1.62	1.63	1.43	.87	.49	.81	.71	.43	.70
1430	1.00	73.5	1.78	1.78	1.60	1.03	.64	.98	.84	.57	.85
1500	1.50	73.5	1.86	1.84	1.70	1.11	.70	1.08	.90	.62	.94
1530	2.00	73.5	1.95	1.93	1.82	1.20	.79	1.20	.98	.70	1.04
1600	2.50	73.5	2.03	2.02	1.93	1.28	.88	1.31	1.04	.78	1.14
1630	3.00	73.5	2.10	2.10	2.02	1.35	.96	1.40	1.10	.85	1.22
1700	3.50	73.5	2.14	2.18	2.14	1.39	1.04	1.52	1.13	.92	1.32
1800	4.50	73.5	2.26	2.38	2.36	1.50	1.24	1.74	1.22	1.10	1.51
2120	7.83	73.5	2.57	3.23	3.09	1.72	2.09	2.47	1.40	1.85	2.15
0930	20.00	73.5	3.01	4.12	3.84	2.26	2.98	3.22	1.84	2.64	2.80
1000	20.50	74.0	0.28	0.83	0.17	2.26	2.98	3.22	1.84	2.64	2.80
1030	21.00	74.0	0.30	0.90	0.17	2.28	3.05	3.22	1.85	2.70	2.80
1100	21.50	74.0	0.33	0.96	0.20	2.34	3.11	3.26	1.90	2.76	2.82
1130	22.00	73.5	0.33	1.01	0.22	2.39	3.16	3.27	1.94	2.80	2.84
1200	22.50	73.5	0.36	1.06	0.24	2.44	3.20	3.29	1.98	2.83	2.86
1230	23.00	73.5	0.39	1.10	0.27	2.48	3.24	3.32	2.02	2.87	2.90
1300	23.50	73.5	0.41	1.17	0.20	2.55	3.31	3.35	2.07	2.93	2.91

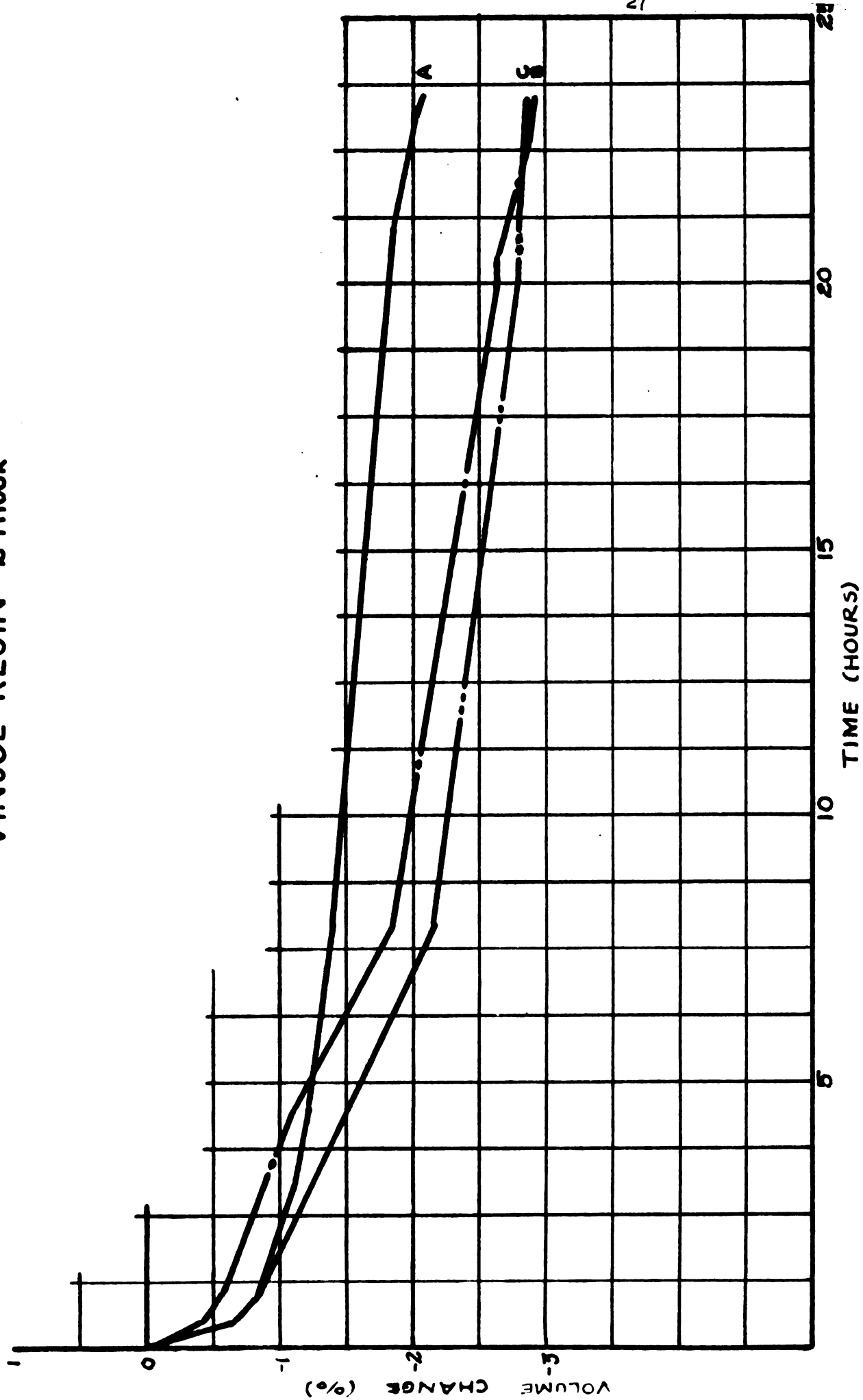
ADD WATER 0.28 0.83 0.17

A VOL. 123.1 CC

B VOL. 112.5 CC

C VOL. 115 CC

VINSOL RESIN - 24_{HOUR}



IRON BOND - 24 HOUR
 PENINSULAR STANDARD CEMENT
 OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:

CEMENT 250G
 WATER 100G
 SAND 417G
 IRON BOND 133G

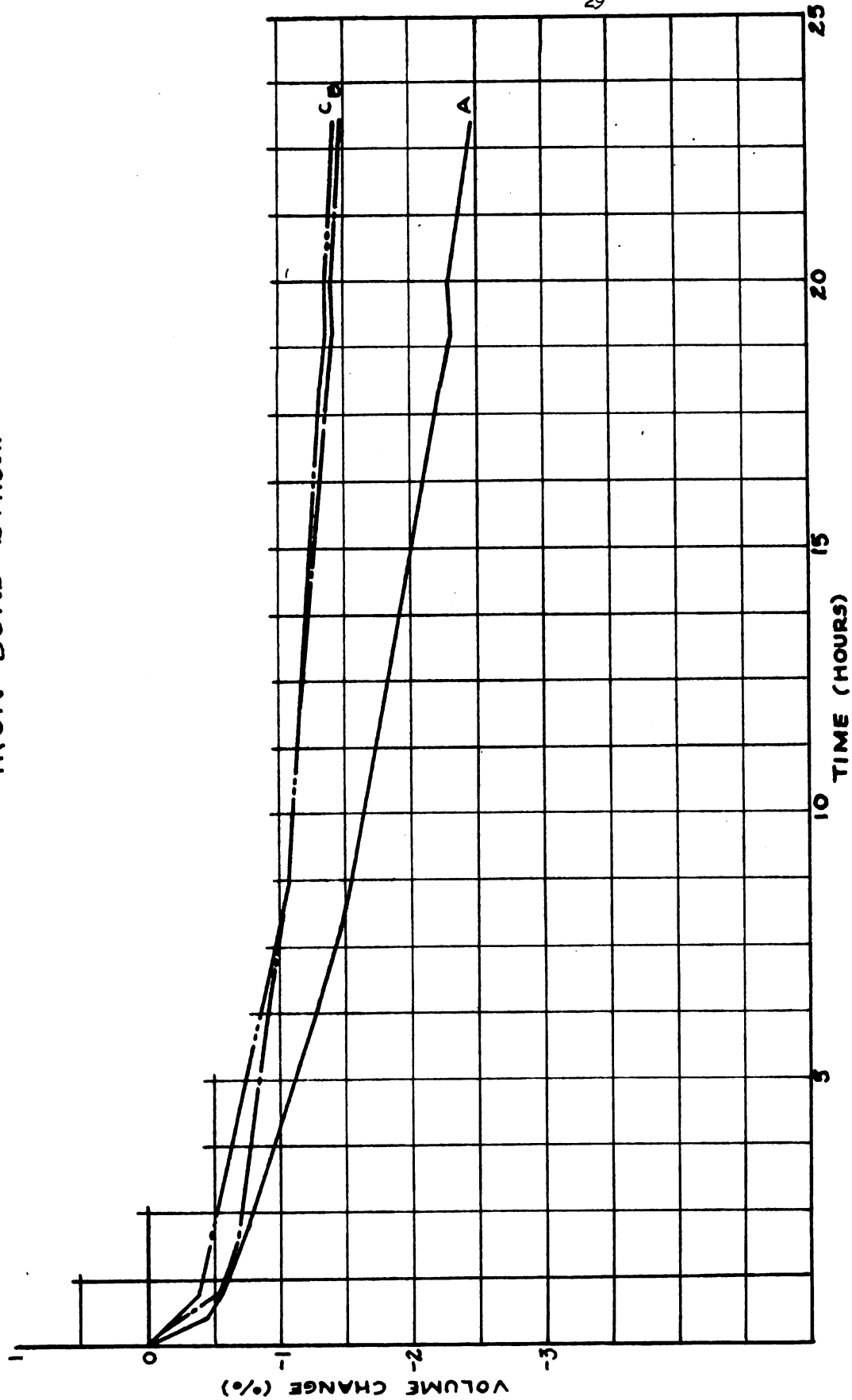
WATER-CEMENT RATIO - .4
 FLOW TABLE - 50

DATA

TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1500											
1530	0	73.5	0.32	0.52	0.34	0	0	0	0	0	0
1600	.50	73.5	0.70	0.53	0.68	.38	.21	.34	.41	.21	.28
1700	1.00	73.5	0.86	0.65	0.82	.53	.33	.48	.56	.54	.39
2130	2.00	73.5	0.99	0.75	0.91	.67	.43	.57	.71	.68	.47
2245	6.50	74.0	1.54	1.22	1.43	1.22	.90	1.09	1.30	.92	.89
2330	7.75	73.5	1.68	1.31	1.55	1.36	.99	1.21	1.45	1.01	1.00
0900	8.50	74.0	1.75	1.35	1.62	1.43	1.03	1.28	1.52	1.05	1.05
1000	18.00	73.5	2.42	1.67	1.97	2.10	1.35	1.63	2.23	1.38	1.34
1100	19.00	73.5	2.50	1.72	2.02	2.18	1.40	1.68	2.32	1.43	1.38
1300	20.00	73.5	2.48	1.70	2.00	2.16	1.38	1.66	2.30	1.41	1.36
1400	22.00	73.5	2.60	1.75	2.07	2.28	1.43	1.73	2.43	1.46	1.41
	23.00	73.5	2.64	1.77	2.10	2.32	1.45	1.76	2.47	1.48	1.44

A VOL. 93.5cc B VOL. 98.4cc C VOL. 122.4cc

IRON BOND - 24 HOUR



FLY ASH - 24 HOUR

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:

CEMENT 250g
WATER 133g
FLY ASH 83g
SAND 602g

WATER-CEMENT RATIO - .4
FLOW TABLE - 50

DATA

TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1230	0	73.5	0.36	0.41	0.44	0	0	0	0	0	0
1300	.50	73.5	0.34	0.38	0.40	+0.04	+0.03	+0.04	+0.03	+0.02	+0.03
1330	1.00	73.5	0.48	0.50	0.52	.12	.19	.08	.09	.13	.07
1430	2.00	73.5	0.71	0.73	0.75	.35	.32	.31	.27	.22	.26
1500	2.50	73.5	0.81	0.83	0.85	.45	.42	.41	.35	.29	.34
1530	3.00	73.5	0.89	0.91	0.93	.53	.50	.49	.41	.35	.40
1600	3.50	73.5	0.97	1.00	1.03	.61	.59	.59	.47	.41	.49
1930	7.00	74.0	1.22	1.24	1.36	.86	.83	.92	.66	.56	.76
2000	7.50	74.0	1.28	1.32	1.46	.92	.91	1.02	.71	.64	.84
2030	8.00	74.0	1.36	1.40	1.57	1.00	.99	1.13	.77	.69	.93
2315	10.75	74.0	1.72	1.84	2.15	1.36	1.43	1.71	1.05	1.00	1.41
0830	20.00	73.5	2.42	3.04	3.02	2.06	2.63	2.58	1.58	1.77	2.13
0900	20.50	73.5	2.56	3.10	3.04	2.20	2.69	2.60	1.69	1.82	2.14
0930	21.00	73.5	2.60	3.13	3.06	2.24	2.72	2.62	1.72	1.92	2.16
1000	21.50	73.5	2.62	3.18	3.09	2.26	2.77	2.65	1.74	1.94	2.18
1030	22.00	73.5	2.66	3.20	3.10	2.30	2.79	2.66	1.77	1.95	2.20
1100	22.50	73.5	2.67	3.22	3.11	2.31	2.81	2.67	1.78	1.96	2.21
1200	23.50	73.5	2.73	3.24	3.13	2.37	2.83	2.69	1.82	1.98	2.21

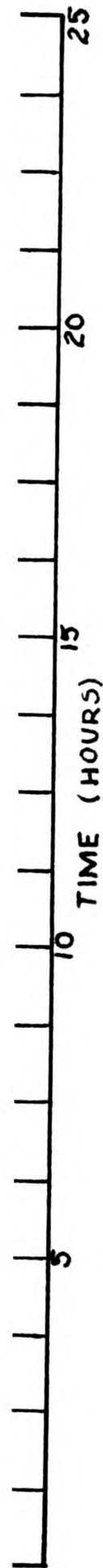
A VOL. 130.4 cc

B

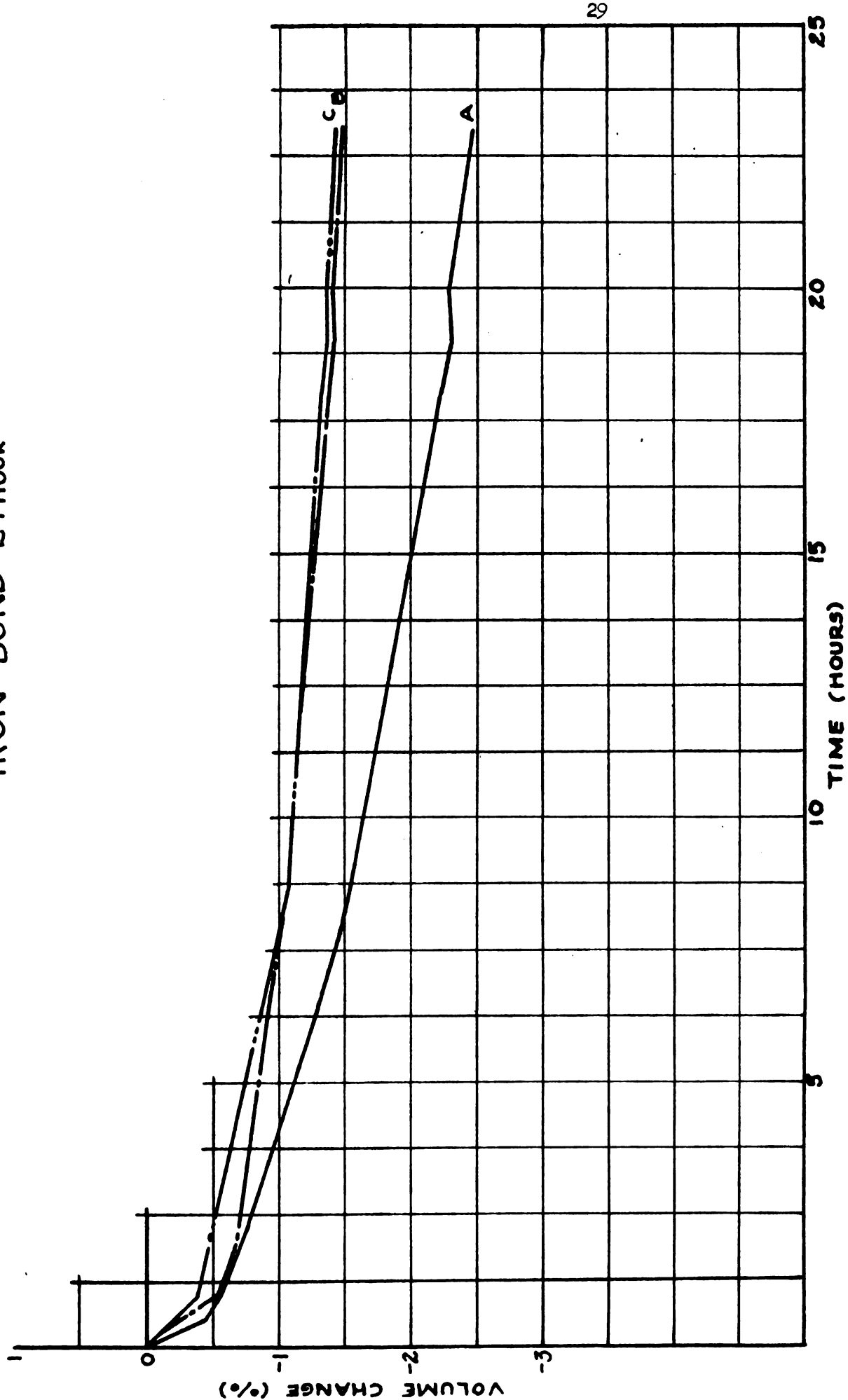
VOL. 143 cc

C

VOL. 121.2 cc



IRON BOND - 24 HOUR



FLY ASH - 24 HOUR

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:

CEMENT 250g
WATER 133g
FLY ASH 83g
SAND 602g

WATER-CEMENT RATIO - .4
FLOW TABLE - 50

DATA

TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE		
			A	B	C	A	B	C	A	B	C
1230	0	73.5	0.36	0.41	0.44	0	0	0	0	0	0
1300	.50	73.5	0.34	0.38	0.40	+0.04	+0.03	+0.04	+0.03	+0.02	+0.03
1330	1.00	73.5	0.48	0.50	0.52	.12	.19	.08	.09	.13	.07
1430	2.00	73.5	0.71	0.73	0.75	.35	.32	.31	.27	.22	.26
1500	2.50	73.5	0.81	0.83	0.85	.45	.42	.41	.35	.29	.34
1530	3.00	73.5	0.89	0.91	0.93	.53	.50	.49	.41	.35	.40
1600	3.50	73.5	0.97	1.00	1.03	.61	.59	.59	.47	.41	.49
1930	7.00	74.0	1.22	1.24	1.36	.86	.83	.92	.66	.56	.76
2000	7.50	74.0	1.28	1.32	1.46	.92	.91	1.02	.71	.64	.84
2030	8.00	74.0	1.36	1.40	1.57	1.00	.99	1.13	.77	.69	.93
2315	10.75	74.0	1.72	1.84	2.15	1.36	1.43	1.71	1.05	1.00	1.41
0830	20.00	73.5	2.42	3.04	3.02	2.06	2.63	2.58	1.58	1.77	2.13
0900	20.50	73.5	2.56	3.10	3.04	2.20	2.69	2.60	1.69	1.82	2.14
0930	21.00	73.5	2.60	3.13	3.06	2.24	2.72	2.62	1.72	1.92	2.16
1000	21.50	73.5	2.62	3.18	3.09	2.26	2.77	2.65	1.74	1.94	2.18
1030	22.00	73.5	2.66	3.20	3.10	2.30	2.79	2.66	1.77	1.95	2.20
1100	22.50	73.5	2.67	3.22	3.11	2.31	2.81	2.67	1.78	1.96	2.21
1200	23.50	73.5	2.73	3.24	3.13	2.37	2.83	2.69	1.82	1.98	2.21

A VOL. 130.4 cc

B

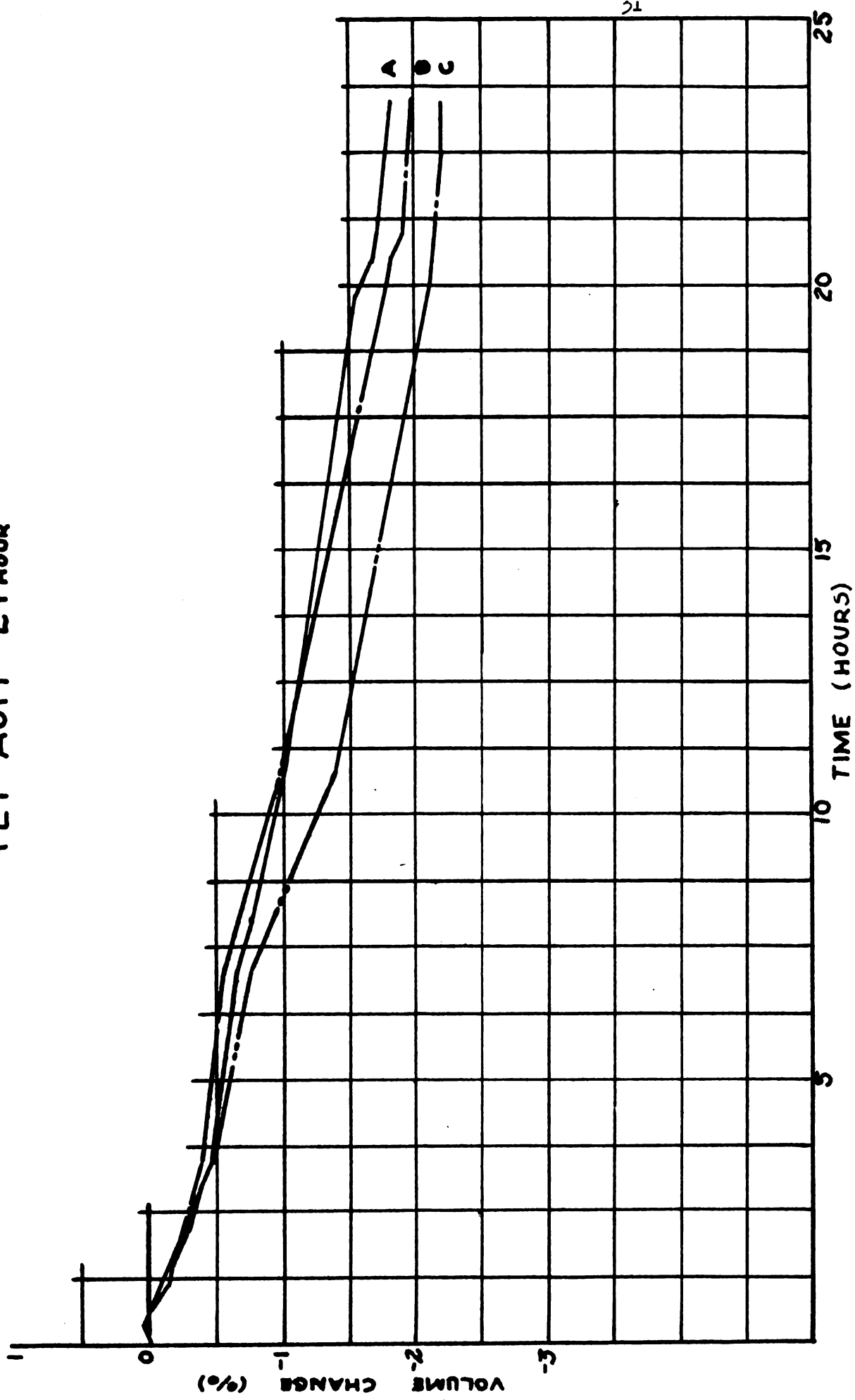
VOL.

143 cc

C

VOL. 121.2 cc

FLY ASH - 24 HOUR



HYDROPEL - 24 HOUR

PENINSULAR STANDARD CEMENT
OTTAWA SAND A.S.T.M. C109 37T

PROPORTIONING:

CEMENT 250g
WATER 100g
SAND 595g
HYDROPEL 39.5cc

WATER-CEMENT RATIO - .4

FLOW TABLE - 50

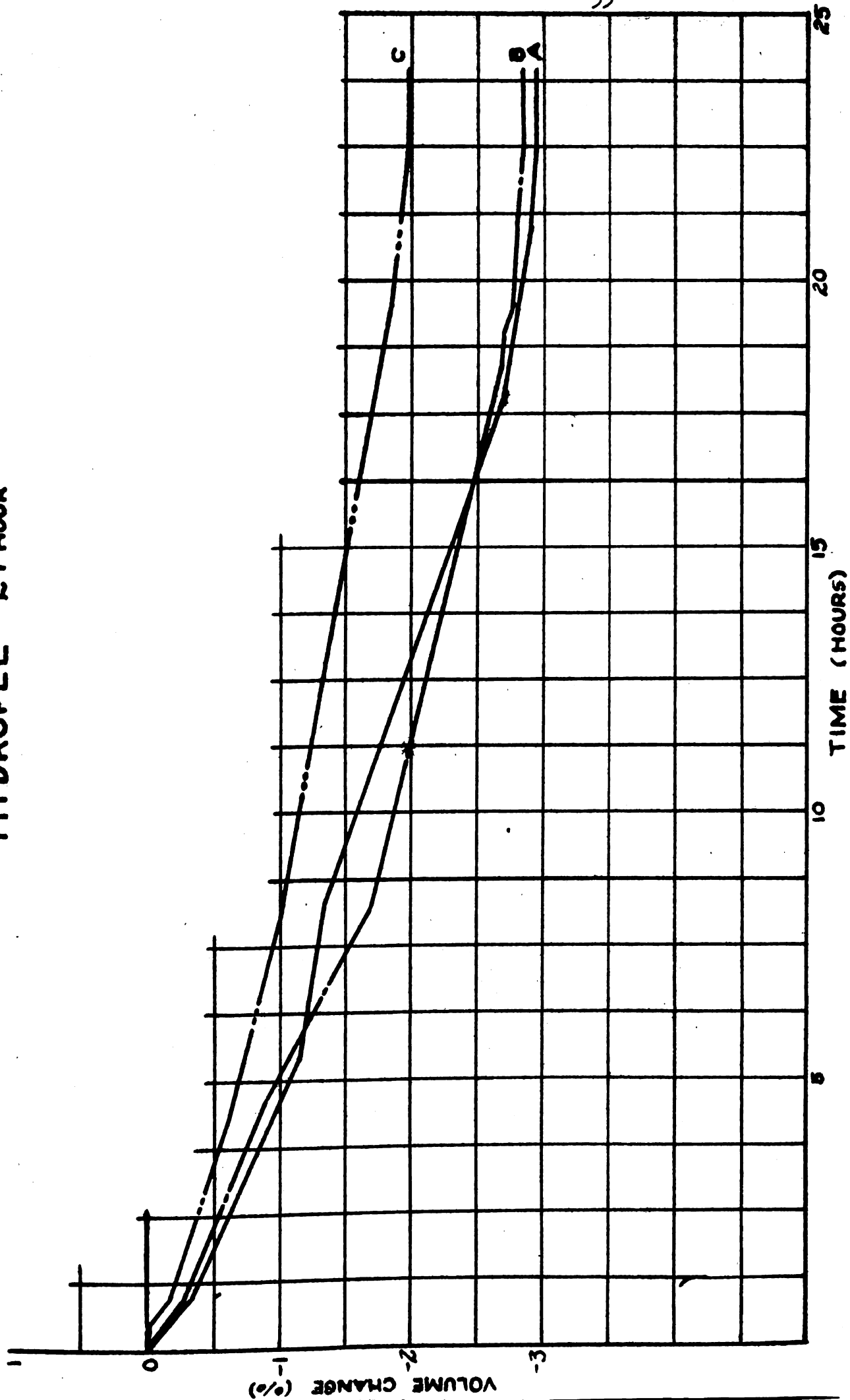
DATA

TIME	HOURS	TEMP °F	READINGS			DIFFERENCE			VOLUME CHANGE (%)		
			A	B	C	A	B	C	A	B	C
1500	0	73.5	0.14	0.36	0	0	0	0	0	0	0
1530	.50	73.5	0.33	0.47	0.03	.19	.11	.03	.16	.09	.02
1600	1.00	73.5	0.54	0.70	0.21	.40	.34	.21	.34	.28	.17
1930	4.50	74.0	1.26	1.40	0.80	1.12	1.04	.80	.97	.87	.65
2000	5.00	74.0	1.36	1.52	0.84	1.22	1.16	.84	1.06	.97	.68
2030	5.50	74.0	1.46	1.66	0.92	1.32	1.30	.92	1.15	1.08	.75
2315	8.25	74.0	*2.02	*2.40	*1.25	1.88	2.04	1.25	1.63	1.70	1.02
0830	17.50	73.5	1.49	0.68	0.90	3.06	5.13	2.08	2.66	2.60	1.69
0900	18.00	73.5	1.56	0.74	0.94	3.16	5.19	2.12	2.71	2.66	1.72
0930	18.50	73.5	1.59	0.76	0.97	3.21	3.21	2.15	2.74	2.68	1.75
1000	19.00	73.5	1.64	0.80	1.01	3.24	3.25	2.19	2.79	2.70	1.78
1030	19.50	73.5	1.67	0.86	1.04	3.27	3.31	2.22	2.81	2.76	1.80
1100	20.00	73.5	1.70	0.88	1.10	3.33	3.33	2.28	2.84	2.78	1.85
1200	21.00	73.5	1.76	0.91	1.15	3.39	3.36	2.33	2.90	2.80	1.90
1330	22.50	73.5	1.82	0.97	1.24	3.39	3.42	2.42	2.95	2.85	1.97
1500	24.00	73.5	1.82	0.97	1.24	3.39	3.42	2.42	2.95	2.85	1.97

* ADD WATER 0.41 - .41 0.07

A VOL. 233 CC - 114.2 = 118.8cc B VOL. 120cc C VOL. 123cc

HYDROPEL - 24 HOUR



Conclusions

1. The final method for measuring the volume change was satisfactory and could be used in future tests. This method could easily be used to measure the volume change of concrete mixes by using the same type apparatus but larger in size.

2. The correlation between a concrete mix and a mortar mix could not be set up with the set of data obtained. Although the various cement mortars tested attained the same relative position on the graph as the concrete mixes, the curve tendencies are different. In only one case, Portland Cement- 24 hour, did an early expansion occur and this expansion only lasted for slightly better than a half an hour. In concrete mixes expansion occurs for about the first ten hours and then the contraction takes place according to the existing data.

3. The data comparison tables do not check with adequate accuracy against each other and the whole series would have to be run again and the results checked against each other.

4. The original intent of this thesis has been fulfilled however there was found to be no comparison between the early volume change of a concrete mix and a mortar mix .

1978

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03177 7158