INCREASING THE TENSILE STRENGTH OF CONCRETE BY USE OF ADMIXTURES

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INCREASING THE TENSILE STRENGTH OF CONCRETE BY USE OF ADMIXTURES

BY

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L. A. R.

PURPOSE

To find an admixture for portland cement that will economically increase the tensile strength of the cement paste sufficiently to eliminate cracking in ordinary structures.

INDEX

PART I

PART II

BRIEF HISTORY

Egyptian massive masonry is the first record of present day methods of bonding stone with mortar. The cementing material was gypsum (burnt). Lime was not used in Egypt until the advent of the Roman period. The gypsum was quarried in an impure state and poorly burned so that it set unevenly and, not being totally decomposed, would give the impression that lime was used. Lime was more abundant but required more fuel, and fuel was scarce.

It is probable that the use of lime as a mortar came from Persia to Greece, thence to Rome. The mortar was prepared by slaking lime and mixing with sand (modern practice). The Romans had the art well perfected, but with the fall of the Roman empire all of this was lost. Medieval mortars were very poor.

In 1765 Loriot, engineer on the waterworks at Versailles, added quicklime to the mortar to obtain increased strength and impermeability. DeLafaye contested this and recommended that egg-sized lumps of lime should be immersed in water, transferred after a time to a cask and there allowed to slake. Ancient writers state that lime had to be slaked for years before using. Rondelet discovered that it was not the method of slaking the lime, but the thoroughness of mixing and ramming the mortar that made the Roman work excel. Chemical analysis, texture, and Indian practices confirm this. The tamping was so thorough that even today the interior mortar is not set.

Greeks and Romans used a volcanic ash, finely ground and mixed with lime and sand, to make a mortar that was superior in strength and would resist water. Santorin earth in Greece, Pozzolana in Rome, and Trass in Russia and Germany are of this source. The Romans created artificial Pozzolana by grinding up tile.

The middle ages lost the art of burning lime and the knowledge of artificial or natural Pozzolana, Trass or Santorin earth. In evidence are the very poor buildings of the ninth, tenth and eleventh centuries. Beginning with the twelfth century we notice a gradual improvement in quality so that by the beginning of the fifteenth century excellent mortar is again in evidence.

The father of modern cement is John Smeaton. His investigations led to the use of "blue lias hydraulic lime" and pozzolana (1756).

The forerunner of "portland cement" is credited to L. J. Vicat. He prepared an artificial hydraulic lime by calcining an intimate mixture of limestone and clay, ground together in a wet mill. Many such attempts were being made during this period, the object being to duplicate what nature had done in creating a natural cement material in the volcanic ash.

Natural cements; i.e., Trass, Possalana, are materials formed by calcining a naturally occuring mixture of calcareous and argillaceous substances at a temperature below that at which sintering takes place.

Vicat, Fremy, Winkler, Michaelis and Le Chatelier all contributed to the physical and chemical analysis of portland cement, but systematic work on portland cement was begun in the United States in the Geophysical Laboratory of the Carnegie Institute at Washington, D. C. in 1906. Since 1926 the P. C. A. has done much to improve cement.

Concrete is described by Vitruvius and is found in the vaults of the Thermae and Basilica of Constantine; its use is at least that old. The Pantheon has concrete walls twenty feet thick. The Roman concrete was far superior to medieval concrete and was not equalled until the construction of the West India docks in 1800.

Chemical Analysis as Known Today

The chemicals in today's portland cement are CaO, $CaOH$, MgO, SiO_2, Al_2O_3 and FeO.

The compounds formed by the addition of water and letting set are: $3CaO-SiO_2$, $2CaO-SiO_2$, $3CaO-Al_2O_3$, $3CaO-2SiO_2$, $5CaO-3Al_3O_3$, $CaO-Al_2O_3$, $3CaO-5Al_2O_3$, $2CaO-Al_2O_3-SiO_2$, $2CaO-Fe_2O_3$, $CaO-Fe_2O_3$, $4CaO-Al_2O_3-Fe_2O_3$.

Tricalcium silicate ($3CaO-SiO_2$) has all the essential properties of portland cement. It has initial and final set within a few hours after gauging and shows no unsoundness. Gypsum affects time of setting.

Dicalcium silicate ($2CaO-SiO_2$) has no definite setting time and sets only slowly over a period of days and months. Gypsum does not affect time of setting.

Tricalcium Aluminate ($3CaO-Al_2O_3$) gives a flash set.

The remaining compounds have been considered as negligible. Table I shows a strength analysis of the three major compounds.

The relation of the strength of cements to their composition has been a rather intractable problem and the factors determining strength apparently are so numerous that any solution has seemed far off. The increase in our knowledge of the constitution of cement and of the compounds present in it has, however, in recent times paved the way for some interesting work on this problem. The calculation of the contents of the various compounds in cement, erroneous to some extent as the values obtained may be, provides a preliminary basis for the allocation of strength. The compound contents, however, are far from providing all the data required for the purpose, because the strength of a cement is dependent also on the fineness to which it is ground and to some extent on the amount of gypsum added; it may perhaps be influenced to some degree by some effects, at present unknown, of minor components such as the alkalis.

Tests show that the strength of any mixture at any time might compare favorably with a ratio of the strengths of the separate parts as established in Table I. There are an insufficient number of tests to prove this; the only thing we know is that tricalcium silicate is mainly responsible for strength development up to twenty-eight days and that dicalcium silicate makes increasing contributions from twenty-eight days on. See Table III. Reference 1, 19, 2.

Portland cement on contact with water produces hydrated compounds in solution which, owing to their insoluble nature, become highly supersaturated. The decomposing and dissolving influence of the water upon the cement going on for some time reaches a point at which the supersaturated solution surrounding the cement coagulates. The gel layer forms about the cement grains and makes it more difficult for the grains to become hydrated, dicalcium silicate taking years, tricalcium silicate a few weeks and tricalcium aluminate a very short time. The gel is apparently a silica gel which in its final geological process would be flint of agate. It seems that if a method of stepping up this process could be obtained then we would get a better concrete. The gel is apparently amorphous.

Tests made by Grun in which he reground cement which had set three days, and then reset three days, reground and reset again, show that in three days apparently only sixty-seven percent of the cement hydrated. See Table VII.

Although, as previously stated, gypsum probably affects the strength of cement to some extent, from the information available it is safe to say that gypsum has no effect on the ultimate strength.

Admixtures Tried and Results

Celite. Celite has no effect on the modulus or strength of concrete up to twenty-eight days. Reference 14.

Vegetable Oils. Vegetable oils are destructive. Reference 15.

Al. or Fe. Together or separately will increase strength. Reference 20.

Water glass. Harmful efflorescent action on concrete. Reference 24.

Sodium chloride. Increased the tensile strength of cement. The difference is decidedly significant. Reference 25.

Tricosol. One percent tricosol will allow ten percent reduction in water, will increase compressive strength eighteen percent and tensile strength forty-three percent. Reference 17.

Gypsum, Sucrose, Calcium Chloride, Tannic Acid

Triethanolamine, $Ca\ (AcO)_2\ H_2SiF_6$. The detrimental effects offset the good. Reference 30.

Zinc Phosphate. Reference 27.

Common salt. Improved the tensile strength of mortars. Reference 25.

Tests with commercial and non-commercial admixtures in percentages ranging from two to fifteen percent of the cement. Indicate that slightly hydraulic admixtures showed only small increase in strength and non-hydraulic admixtures showed reduction in strength up to about five percent for each one percent of admixture in terms of weight of cement. Colloidal clays and diatomaceous earth gave greatest reductions in strength and, in general, reduction was greater at one to three days than at greater ages. Reference 21.

The addition of arsenious oxide (As_2O_3). A thirty percent admixture gave forty percent increase in compressive strength at seven days and ninety days. The mixture has to be made at 320 to 374 degrees F. Reference 18.

Electric Heating of Concrete. This interesting article describes the experiments and experiences gained from the use of electric heating of concrete for cold weather construction. Reference 3.

From the literature available we conclude:

1. That fineness of grinding and the combined lime and silica present determine the aged strength.
2. A raised early strength and lowered late strength of mixtures may be the result of alumina containing compounds mixed with the calcium silicates in the absence of a retarder. The addition of tricalcium aluminate causing a reduction in

the water available to the tricalcium silicate may be responsible for the increase in early strength. The development of tricalcium aluminate hydrate paste may influence a lowered late strength. The influence of the alumina containing compounds is attributed to the rapid development of a weak and open structure by the crystalline tricalcium aluminate hydrate; thus preventing optimum contacts of the hydrating calcium silicate grains.

3. The distribution of the water is as essential a factor as the total amount of water in combination. The structure and nature of the hydration of the colloidal calcium silicate hydrate appear to establish the rate of development of compressive strength, and not by hydrolysis or by the total fixed water of hydration.
4. Tricalcium aluminate hydrate, a fluffy crystalline isotropic hydrated calcium aluminate, is formed rapidly when alumina compounds are treated with water.
5. The compounds chiefly responsible for high compressive strength in portland cement are tricalcium silicate and beta-dicalcium silicate, gauged with water to make a paste.
6. Tricalcium silicate reacts with water rapidly,

both by hydrolysis and hydration; beta-dicalcium silicate remains practically unhydralyzed but combines with water to form fixed water of hydration, very slowly during the first month, but approaching the hydration value attained by tricalcium silicate in a year.

7. Crystalline calcium hydroxide and amorphous hydrated calcium silicate, of composition approaching the beta-dicalcium silicate hydrates to approximately the same amorphous hydrated silicate, are products of the reaction of water on tricalcium silicate. Traces of crystalline calcium hydroxide have been observed.

8. Crystalline tricalcium aluminate hydrate and an amorphous hydrate (the composition of which has not been definitely established) are products of the reaction of quadra calcium aluminate ferrate and water.

9. The quadra aluminate ferrate and the dicalcium ferrate, mixed with the calcium silicates in the absence of a retarder, lower the compressive strength of the mixtures. It is suggested that this may be due in part to the precipitation upon the grains of the hydrating calcium silicates of amorphous calcium ferrate hydrate, thus retarding the rate of impenetration of the water and reducing the bonding action.

10. The initial set is retarded by the use of gypsum. Gypsum reacts with the alumina that enters into solution with the formation of crystalline calcium sulphoaluminate; this occasions a delay in the development of the crystalline hydrated tricalcium aluminate.

11. Gypsum tends to counteract the influence of the alumina in lowering the compressive strengths of the calcium silicates. It is suggested that this favorable influence may be associated with a retardation in the development of the tricalcium aluminate hydrate due to effects of the prior formation of calcium sulfoaluminate permitting the structure of the set paste to be established by the hydrating tricalcium silicate.

12. Gypsum also tends to counteract the influence of the ferric-oxide containing compounds in lowering the compressive strengths of the calcium silicates. It is suggested that this favorable influence may be associated with the formation not only of calcium sulfoaluminate, as above, but also of the calcium sulfoferrite and the consequent reduction in the amount of the amorphous ferrite hydrate that can be deposited on the grains of the calcium silicates.

13. Dicalcium silicate produces nothing but gel;

so even if it had early strength it would be of no value. All-purpose cement cannot be made from any one compound. The compounds have an optimum proportion one to another.

14. Amorphous silicate, upon crystallization, becomes agate quartz (SiO_2 hardness 7, specific gravity 2.65 and crystalline) or Calcite ($CaCO_3$ hardness 3, specific gravity 2.70 and crystalline) (limestone or marble).

15. Control in time of setting is facilitated by increasing silica and decreasing alumina.

16. Delayed development of full strength may be obtained by increasing silica at expense of lime.

17. Steam curing does not develop any strength but develops the strength in a shorter time.

References: 1,2,5,7,8,9,10,
11,13,26.

TABLE I

TENSILE STRENGTH OF CEMENT COMPOUNDS STORED IN WATER

NEAT CEMENT

MIXTURE	1	7	28	91	182	365
(1) $2CaO\ SiO_2$	-	-	98	538	616	718
(2) $3CaO\ SiO_2$	440	698	772	683	657	642
(3) $3CaO\ Al_2O_3$	100	135	125	-	-	-
81%(1) 19%(3)	98	105	192	376	380	614
81%(2) 19%(3)	267	665	908	562	551	603
50%(2) 50%(1)	166	362	527	670	576	778
40.5%(1) 40.5%(2) 19%(3)	307	432	671	681	671	803

1:3 MORTAR

MIXTURE	7	28	182	365
(1) $2CaO\ SiO_2$	-	23	194	225
(2) $3CaO\ SiO_2$	270	407	371	-
(3) $3CaO\ Al_2O_3$	-	-	-	-
81%(1) 19%(3)	40	58	260	387
81%(2) 19%(3)	330	395	356	-
50%(2) 50%(1)	119	220	320	-
40.5%(1) 40.5%(2) 19%(3)	198	247	335	-

Data after Bates 3% Plaster of Paris (1.65% SO_3) added except C_3A 10% added.

TABLE II

CEMENTING MIX	1:3 MORTARS WATER STORED		
	3ds	7ds	28ds
$3CaO\ SiO_2$	114	199	220
$3CaO\ SiO_2$ (5% gypsum)	156	199	313
75% $3CaO\ SiO_2$ 25% $3CaO\ Al_2O_3$	214	284	455
$3CaO\ Al_2O_3$	-	-	43
60% $3CaO\ SiO_2$ 20% $3CaO\ Al_2O_3$ 20% gypsum	214	-	270

Bates

TABLE III

MIXTURE	7ds	28ds	90ds	180ds
70% $3CaO\ SiO_2$ 10% $2CaO\ SiO_2$	5000	6800	6800	6800
30% $3CaO\ SiO_2$ 50% $2CaO\ SiO_2$	1200	2800	5000	6200

TABLE IV

	CONCRETE COMPRESSIVE					MORTAR TENSILE			
No.	1ds	3ds	7ds	28ds	365ds	1ds	3ds	7ds	28ds
1	940	2330	3300	4650	5750	319	492	579	644
2	950	3420	4580	5250	6840	378	525	610	666
3	1180	2220	3020	4520	5760	415	494	530	644
4	750	2700	4400	5350	6160	381	523	631	615
5	1530	3720	4790	5390	6000	455	552	628	626
6	530	1960	3480	5500	6070	349	501	607	632
7	855	2630	3780	4770	6490	351	473	527	610
8	625	2700	4450	5550	5830	425	512	526	588
9	870	3250	4690	5580	5870	424	563	604	668

1:2:4 mix, water cured and water cement ratio .60(wt.)

1:3 mortar water cured (both)

TABLE V

No.	CaO	MgO	Al_2O_3	Fe_2O_3	SiO_2	TiO_2	NaO_2	K_2O	SO_3
1	65.6	.30	5.48	2.79	21.42	0.45	0.36	0.61	2.49
2	62.1	1.12	5.69	3.99	21.18	0.29	0.12	0.77	3.10
3	61.3	2.32	7.32	3.50	19.45	0.38	0.27	1.03	4.00
4	63.8	3.27	6.49	2.74	18.15	0.36	0.23	0.55	2.49
5	66.1	0.92	5.16	2.36	19.69	0.38	0.38	0.40	3.11
6	64.7	2.72	4.93	3.33	19.52	0.29	0.37	0.85	2.21
7	65.4	0.87	5.42	3.07	20.64	0.27	0.59	0.39	2.05
8	66.9	0.65	6.28	2.90	19.38	0.39	0.22	0.79	1.89
9	66.3	0.86	4.80	2.42	20.78	0.29	0.60	0.42	2.48

TABLE VI

No.	CaO	$4CaO\ Al_2O_3\ Fe_2O_3$	$3CaO\ Al_2O_3$	$3CaO\ SiO_2$	$2CaO\ SiO_2$	Flour
1	1.3	9	10	51	23	75
2	.5	12	8	56	11	77
3	1.1	11	14	31	33	69
4	2.0	8	13	55	12	79
5	3.7	7	10	57	13	83
6	1.9	10	7	63	9	65
7	3.5	9	9	48	23	75
8	2.9	9	12	62	9	69
9	1.7	7	9	62	13	77

TABLE VII

No.	A	B	C	D	E	F	G	H	I
1	2.78	0.94	0.94	0.92	0.91	1.03	0.95	2.59	1.96
2	2.96	1.00	1.00	0.99	0.98	1.07	1.02	1.88	1.42
3	2.64	0.90	0.90	0.88	0.86	0.96	0.95	1.80	2.09
4	3.05	1.04	1.03	1.00	1.00	1.11	1.12	1.97	2.37
5	3.01	1.01	1.02	0.98	0.99	1.10	1.07	2.36	1.48
6	3.02	1.01	1.02	0.98	0.99	1.10	1.07	2.36	1.48
7	2.80	0.98	0.98	0.92	0.94	1.06	0.99	2.43	1.76
8	3.04	1.04	1.03	0.99	1.00	1.12	1.05	2.11	2.16
9	2.93	1.01	0.99	0.96	0.96	1.09	1.01	2.88	1.98

A - CaO / $(SiO_2\ Al_2O_3)$

B - CaO / $(2.8SiO_2\ \ 1.10Al_2O_3\ \ 0.70Fe_2O_3)$

C - CaO / $(2.88SiO_2\ \ 1.18Al_2O_3\ \ 0.65Fe_2O_3)$

D - $(CaO\text{-Free } CaO)$ / $(2.8SiO_2\ \ 1.18Al_2O_3\ \ .65Fe_2O_3)$

E - CaO / $(2.8\ SiO_2\ \ 1.65Al_2O_3\ \ .35Fe_2O_3)$

F - CaO / $(2.33SiO_2\ \ 1.65Al_2O_3\ \ 1.05Fe_2O_3)$

G - $(CaO\ \ 1.4MgO)$ / $(2.8SiO_2\ \ 1.1Al_2O_3\ \ 0.7Fe_2O_3)$

H - SiO_2 / $(Al_2O_3\ \ Fe_2O_3)$

I - Al_2O_3 / Fe_2O_3

TABLE VIII

3 days	3170	940	256
7 days	3940	1310	355
28 days	6000	1850	655

Grun

TABLE IX

1:3 SAND MORTARS AT 7 DAYS

WATER CEMENT RATIO

Percent water	Tensile strength lbs. per sq. in.
8	410
9	400
10	340
11	280
12	230

TABLE X

1:3 SAND MORTARS WATER CEMENT RATIO	COMPRESSIVE STRENGTH		
W/C	7 ds	28 ds	90 ds
0.52	725	1114	1407
0.56	777	1230	1866
0.60	1053	1484	2292
0.64	1084*	1640	2395*
0.68	1040	1682*	2310
0.72	784	1613	2290
0.76	760	1425	2170

* inconsistent

TABLE XI

EFFECT OF CURING

		3ds.	7ds.	28ds.	1yr.
Test 1	**air cured**	345	434	419	
	water cured	324	528	562	671
Test 2	air cured	458	517	554	
	water cured	501	607	632	623

TABLE XII

EFFECT OF TEMPERATURE

	Temp."F"	1 ds.	3 ds.	7 ds.	28 ds.
Normal cement	2	-	199	800	1916
	11	-	564	1158	2248
	17	373	925	1472	2625
	25	493	1096	1586	2946
	35	620	1349	1956	3036
High early strength cement	2	50	459	1961	3846
	11	225	1443	2469	3604
	17	575	1951	2831	4076
	25	1106	2221	2865	4263
	35	1686	2698	3004	4043

TABLE XIII

STEAM CURING

TEST	STEAM AT 100 DEGREES FOR 16 HOURS THEN WATER AT 22 DEGREES			OR MOIST AIR AT 22 DEGREES		
No.	1ds.	7 ds.	28 ds.	1 ds.	7 ds.	28 ds.
1	195	200	200	75	345	470
2	300	305	355	75	290	465
3	215	210	220	200	500	520
4	160	170	185	55	255	405

#3 was quick setting cement.

TABLE XIV

CONCRETE STORED IN MOIST AIR 24 HOURS BEFORE STEAM IS APPLIED

STEAM PRESSURE	68		103		197		MOIST AIR	
TIME OF CURING	18hrs.	42hrs.	18hrs.	42hrs.	18hrs.	42hrs.	7ds.	28ds.
1	2660	5480	5350	7140	6970	7600	5280	6340
2	3330	5050	5120	5470	6000	7030	5480	6200
3	3550	5470	4760	6670	5730	6790	2740	5080
4	3460	5760	5580	7160	6110	6760	2560	5080

TABLE XV

CEMENT	7 ds.	28 ds.
Clinkered	358	421
Melted	220	306

TABLE XVI

CHEMICAL PROPORTIONING OF PORTLAND CEMENT WITHIN LIMITS

CaO	60 - 70	Fe_2O_3	0.5 - 6
SiO_2	17 - 25	MgO	0.1 - 5.5
Al_2O_3	3 - 8	Na_2O	
SO_3	1 - 3	plus K_2O	0.5 - 1.3

PART II

PREFACE

The effect of chemical composition on the tensile strength of concrete has been quite thoroughly investigated; however, most of it has been on the basis of chemical logic, and we find that many of our most important developments have been illogical in approach or purely accidental. An example of the latter is the discovery of what is marketed today as air-entraining cement. A few years ago highway men were very much concerned over the fact that concrete highways were scaling off, except for a few highways in New York that had all been made of the same cement. Chemical analysis and the knowledge of the plant chemist could not determine why that cement was different from any other; the processes were all alike. The story unravels as follows: In the process of grinding the clinker to the required fineness we make use of a ball mill which is loaded with about six ton of steel balls from two to five inches in diameter. These balls must be cleaned once each twelve hour shift, a very tedious job. The men responsible for the equipment, being very human, were often discouraged with the difficult cleaning job; so one night one of them, having a particularly difficult time, threw a couple of shovels of coal into the mill, hoping it would clean up the balls; and it did. Thereafter he used this method of cleaning the equipment, being very careful not to let anyone see him do it. In due time his partner on the other shift was informed of the method and cautioned to keep quiet about it. The two later discovered that a little grease and one shovel of coal would do the job very well. When the chemist had exhausted all of the chemical analysis he knew he began to question the men in the plant to get their opinion. The ball mill operators did not break down immediately; but later, observing that the chemist was greatly disturbed, they gained his confidence and told him what they had been doing, voicing the opinion that perhaps this was the reason for the different property of that particular cement. The results of tests were positive, and air-entraining cements were on the market. We offer this story to appease any of the chemists who might think that in the work which follows we might have stepped out of bounds.

MIXING, SETTING, CURING AND TESTING PROCEDURE

It was decided to test a few chemicals as admixtures under the following conditions of setting and curing:

"A"

Twelve specimens were made from the sample, placed in forms and left to set under the influence of electric, D. C., current for twenty-four hours. The specimens were then placed in water; at seven, fourteen, twenty-one and twenty-eight day ages respectively, 3 specimens were removed, one tested immediately and two left in air to be tested at about one hundred and forty days. The exact age is given with the data on each sample. The average breaking stress of the two test specimens is recorded.

"B"

Twelve specimens were made from the sample. All specimens were left in forms twenty-four hours and then placed in water. At seven, fourteen, twenty-one and twenty-eight day ages respectively, three specimens were removed from the water, one tested immediately and two left in air to be tested at about one hundred and forty days. The exact age is given with the data on each sample. The average breaking stress of the two test specimens is recorded.

"C"

Twelve specimens were made from the sample, placed in forms and left to set under the influence of electrical, D. C. current for twenty-four hours. Eight specimens were left in air until tested, one at seven, one at fourteen, one at twenty-one, one at twenty-eight and four at about one hundred and seventy-five days. The average of the four breaking stresses is recorded. Four specimens were left in air seven, fourteen, twenty-one and twenty-eight days; then twenty-one, fourteen, seven and seven days in water respectively; then in air until tested at about one hundred and seventy-five days. The exact age is given with the data on the sample.

"D"

Twelve specimens were made from the sample. All specimens were left in forms twenty-four hours, then removed and placed in air. Eight specimens were left in air until tested, one at seven, one at fourteen, one at twenty-one, one at twenty-eight and four at about one hundred and seventy-five days. The exact age is given with the data on each sample. The average breaking stress of the four test specimens is recorded. Four specimens were left in air seven, fourteen, twenty-one and twenty-eight days; then twenty-one, fourteen, seven and seven days in water respectively, then in air until tested at about one hundred and seventy-five days. The exact age is given with the data on the sample.

Test No. 1

Test number one was a control test to determine the current and voltage best suited for these particular test specimens.

It was found that a voltage of near forty with a current of three-tenths ampere was about right for the specimen. This volt-amperage value was small enough so that temperature rise was negligible, and the current was small enough not to cause excessive hydrolysis, but enough to effect a result.

——— ——— ———

Test No. 2

2,860 grams of cement.
988 c.c. of tap water.

Test procedure "A"

——— ——— ———

Test No. 3

Same mix as 2.

Test procedure "B"

——— ——— ———

Test No. 12

Same mix as 2.

Test procedure "A"

——— ——— ———

Test No. 13

Same mix as 2.

Test procedure "B"

______ ______ ______

Test No. 20

Same mix as 2.

Test procedure "C"

______ ______ ______

Test No. 21

Same mix as 2.

Test procedure "D"

______ ______ ______

Test No. 4

2,860 grams of cement.
988 c.c. of tap water.
34 grams of Urea.

Test procedure "B"

______ ______ ______

Test No. 6

Same mix as 4.

Test procedure "A"

______ ______ ______

Test No. 22

Same mix as 4.

Test procedure "D"

______ ______ ______

Test No. 5

2,860 grams of cement.
916.5 c.c. of water.
71.5 c.c. 40% solution formaldahyde

Test procedure "B"

Test No. 15

Same mix as 5.

Test procedure "A"

Test No. 23

Same mix as 5.

Test procedure "D"

Test No. 7

2,860 grams of cement.
28.6 c.c. of phenol
959.4 c.c. of water

Test procedure "B"

Test No. 9

Same mix as 7.

Test procedure "A"

Test No. 25

Same mix as 7.

Test procedure "D"

Test No. 8

2,860 grams of cement.
17 grams of urea.
35.7 c.c. of formaldahyde (40% sol.)
952.3 c.c. of water.

Test procedure "B"

Test No. 16

Same mix as 8.

Test procedure "A"

Test No. 24

Same mix as 8.

Test procedure "D"

Test No. 10

2,860 grams of cement.
35.7 c.c. of formaldahyde (40% sol.)
494 c.c. of carbolic sol. as in 7.
458 c.c. of water.

Test procedure "B"

Test No. 17

Same mix as 10.

Test procedure "A"

Test No. 26

Same mix as 10.

Test procedure "D"

Test No. 11

2,860 grams of cement.
14.3 c.c. of phenol.
17 grams of urea.
973.7 c.c. of water.

Test procedure "B"

——— ——— ———

Test No. 18

Same mix as 11.

Test procedure "A"

——— ——— ———

Test No. 27

Same mix as 11.

Test procedure "D"

——— ——— ———

Test No. 14

2,860 grams of cement.
9.5 c.c. of phenol.
11.3 grams of urea.
23.8 c.c. of formaldahyde.
954.7 c.c. of water.

Test procedure "B"

——— ——— ———

Test No. 19

Same mix as 14.

Test procedure "A"

——— ——— ———

Test No. 28

Same mix as 14.

Test procedure "D"

——— ——— ———

Test No. 41

953 grams of cement.
2,859 grams of sand (Ottawa 30-50).
582 c.c. of water.
9.5 grams of urea.

Test procedure "B"

Test No. 42

953 grams of cement.
2,859 grams of sand (Ottawa 30-50).
558 c.c. of water.
23.8 c.c. of formaldahyde.

Test procedure "B"

Test No. 36

953 grams of cement.
2,859 grams of sand.
582.5 c.c. of water.

Test procedure "B"

Test No. 37

Same mix as 36.

Test procedure "D"

Test No. 38

2,860 grams of cement.
988 c.c. of water.
85.8 grams of Z.

Test procedure "A"

Test No. 39

Same mix as 38.

Test procedure "B"

——— ——— ———

Test No. 40

Same mix as 38.

Test procedure "D"

——— ——— ———

Test No. 43

2,860 grams of cement.
28.6 grams of magnesium sulphate.
988 c.c. of water.

Test procedure "B"

——— ——— ———

Test No. 49

Same mix as 43.

Test procedure "D"

——— ——— ———

Test No. 44

2,860 grams of cement dissolved in solution of ¼ of 1% stearic acid solution in benzine; let dry and powder.
988 c.c. of water.

Test procedure "B"

——— ——— ———

Test No. 45

2,860 grams of cement.
28.6 grams of sodium oxylate.
988 c.c. of water.

Test procedure "B"

——— ——— ———

Test No. 47

Same mix as 45.

Test procedure "D"

______ ______ ______

Test No. 46

953 grams of cement.
2,859 grams of sand (Ottawa 30-50)
588 c.c. of phenol solution (same concentration as used before).

Test procedure "B"

______ ______ ______

Test No. 48

2,860 grams of cement.
28.6 grams of silicate of soda.
988 c.c. of water.

Test procedure "B"

______ ______ ______

TABLE I

SPECIMENS 24 HOURS IN FORMS 6 DAYS IN WATER

Test No.	Chemical Admixture	Breaking stress psi.	Condition of setting
6	U	1480	El.
3	Pl	1430	Pl.
4	U	1380	Pl.
7	C	1300	Pl.
17	C.F.	1275	El.
45	NaO_2	1250	Pl.
12	Pl	1240	El.
2	Pl	1230	El.
5	F	1155	Pl.
48	$NaSiO_2$	1110	Pl.
15	F	1050	El.
13	Pl	1000	Pl.
18	U.C.	990	El.
10	F.C.	912	Pl.
11	U.C.	878	Pl.
43	$MgSO_4$	863	Pl.
8	U.F.	850	Pl.
14	C.U.F.	795	Pl.
16	U.F.	753	El.
44	Spec.	734	Pl.
9	C	660	El.
19	C.U.F.	572	El.
46	S.C.	433	Pl.
36	S	424	Pl.
42	S.F.	169	Pl.
41	S.U.	69	Pl.
38	Z	-	El.
39	Z	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE II

SPECIMENS 24 HOURS IN FORMS 13 DAYS IN WATER

Test No.	Chemical Admixture	Breaking stress psi.	Condition of setting
6	U	1690	El.
13	Pl	1580	Pl.
7	C	1495	Pl.
5	F	1430	Pl.
17	F.C.	1355	El.
18	U.C.	1360	El.
8	U.F.	1350	Pl.
3	Pl	1300	Pl.
2	Pl	1285	El.
10	F.C.	1270	Pl.
15	F	1273	El.
4	U	1230	Pl.
12	Pl	1285	El.
14	C.U.F.	1125	Pl.
11	U.C.	1150	Pl.
43	$MgSiO_2$	1125	Pl.
48	$NaSO_4$	1125	Pl.
45	NaO_2	1050	Pl.
16	U.F.	734	El.
44	Spec.	840	Pl.
36	S	527	Pl.
42	S.F.	130	Pl.
9	C	-	El.
19	C.U.F.	-	El.
46	S.C.	-	Pl.
41	S.U.	-	Pl.
38	Z	-	El.
39	Z	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE III

SPECIMENS 24 HOURS IN FORMS 20 DAYS IN WATER

Test No.	Chemical Admixture	Breaking stress psi.	Condition of setting
6	U	1580	El.
43	$MgSO_4$	1485	Pl.
13	Pl	1450	Pl.
15	F	1440	El.
45	NaO	1440	Pl.
18	U.C.	1425	El.
9	C	1400	El.
12	Pl	1410	El.
10	F.C.	1230	Pl.
8	U.F.	1210	Pl.
5	F	1200	Pl.
4	U	1200	Pl.
48	$NaSiO_2$	1140	Pl.
3	Pl	1120	Pl.
11	U.C.	1115	Pl.
14	C.U.F.	1100	Pl.
44	Spec.	870	Pl.
46	S.C.	650	Pl.
41	S.U.	540	Pl.
36	S	178	Pl.
7	C	-	Pl.
17	F.C.	-	El.
2	Pl	-	El.
16	U.F.	-	El.
19	C.U.F.	-	El.
42	S.F.	-	Pl.
38	Z	-	El.
39	Z	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE IV

SPECIMENS 24 HOURS IN FORMS 27 DAYS IN WATER

Test No.	Chemical Admixture	Breaking stress psi.	Condition of setting
3	Pl.	1710	Pl.
2	Pl.	1640	El.
18	U.C.	1445	El.
10	F.C.	1360	Pl.
17	F.C.	1275	El.
4	U	1250	Pl.
11	U.C.	1223	Pl.
19	C.U.F.	1125	El.
5	F	1050	Pl.
6	U	920	El.
12	Pl.	800	El.
8	U.F.	790	Pl.
36	S	760	Pl.
14	C.U.F.	536	Pl.
7	C	400	Pl.
13	Pl.	351	Pl.
45	NaO_2	-	Pl.
48	$NaSiO_2$	-	Pl.
15	F	-	El.
43	$MgSO_4$	-	Pl.
16	U.F.	-	El.
44	Spec.	-	Pl.
9	C	-	El.
46	S.C.	-	Pl.
42	S.F.	-	Pl.
41	S.U.	-	Pl.
38	Z	-	El.
39	Z	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE V

SPECIMENS 24 HOURS IN FORMS 6 DAYS IN LAB. AIR

Test No.	Chemical Admixture	Breaking stress psi.	Condition of setting
20	Pl	553	El.
49	$MgSO_4$	547	Pl.
26	F.C.	502	Pl.
24	U.F.	482	Pl.
23	F	472	Pl.
27	U.C.	464	Pl.
47	NaO	427	Pl.
25	C	389	Pl.
21	Pl	371	Pl.
37	S	338	Pl.
28	C.U.F.	320	Pl.
22	U	317	Pl.
40	Z	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE VI

SPECIMENS 24 HOURS IN FORMS 13 DAYS IN LAB. AIR

Test No.	Chemical Admixture	Breaking stress psi.	Condition of setting
49	$MgSO_4$	750	Pl.
20	Pl	750	El.
22	U	748	Pl.
21	Pl	657	Pl.
27	U.C.	603	Pl.
25	C	550	Pl.
26	F.C.	373	Pl.
47	NaO	380	Pl.
23	F	376	Pl.
24	U.F.	319	Pl.
37	S.	315	Pl.
28	C.U.F.	-	Pl.
40	Z	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE VII

SPECIMENS 24 HOURS IN FORMS 20 DAYS IN LAB. AIR

Test No.	Chemical Admixture	Breaking stress psi.	Condition of setting
27	U.C.	1115	Pl.
20	Pl	790	El.
25	C	755	Pl.
47	NaO	750	Pl.
26	F.C.	712	Pl.
21	Pl	652	Pl.
22	U	562	Pl.
24	U.F.	550	Pl.
23	F	520	Pl.
37	S	277	Pl.
49	MgSO	180	Pl.
28	C.U.F.	-	Pl.
40	Z	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE VIII

SPECIMENS 24 HOURS IN FORMS 26 DAYS IN LAB. AIR

Test No.	Chemical Admixture	Breaking stress psi.	Condition of setting
27	U.C.	1375	Pl.
22	U	1275	Pl.
21	Pl	1050	Pl.
25	C	1030	Pl.
26	F.C.	1030	Pl.
24	U.F.	440	Pl.
23	F	350	Pl.
37	S	320	Pl.
20	Pl	-	El.
28	C.U.F.	-	Pl.
49	$MgSO_4$	-	Pl.
47	NaO	-	Pl.
40	Z	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE IX

SPECIMENS 24 HOURS IN FORMS 6 DAYS IN WATER
THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN

Test No.	Chemical Admixture	Age days	Breaking stress psi.	Condition of setting
12	Pl	129	870	El.
48	$NaSiO_2$	175	818	Pl.
42	S.F.	175	795	Pl.
14	C.U.F.	149	775	Pl.
36	S	175	750	Pl.
11	U.C.	129	720	Pl.
7	C	115	715	Pl.
44	Spec	175	690	Pl.
41	S.U.	175	680	Pl.
6	U	115	650	El.
19	C.U.F.	175	635	El.
46	S.C.	175	595	Pl.
18	U.C.	146	575	El.
10	F. C.	120	550	Pl.
13	Pl	129	540	Pl.
3	Pl	116	540	Pl.
15	F	148	540	El.
2	Pl	116	475	El.
5	F	116	460	Pl.
9	C	120	440	El.
16	U.F.	147	400	El.
17	U.F.	147	385	El.
43	$MgSO_4$	175	380	Pl.
38	Z	175	390	El.
4	U	116	380	Pl.
45	NaO	175	370	Pl.
8	U.F.	121	370	Pl.
39	Z	175	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE X

SPECIMENS 24 HOURS IN FORMS 13 DAYS IN WATER THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN.

Test No.	Chemical Admixture	Age days	Breaking stress psi.	Condition of setting
48	$NaSiO_2$	175	976	Pl.
13	Pl	129	860	Pl.
42	S.F.	175	855	Pl.
36	S	175	815	Pl.
41	S.U.	175	760	Pl.
46	S.C.	175	720	Pl.
44	Spec	175	650	Pl.
2	Pl	116	600	El.
12	Pl	129	600	El.
14	C.U.F.	149	550	Pl.
16	U.F.	147	545	El.
11	U.C.	129	520	Pl.
15	F	148	520	El.
5	F	116	490	Pl.
8	U.F.	121	470	Pl.
45	NaO	175	430	Pl.
9	C	120	470	El.
10	F.C.	120	410	Pl.
3	Pl	116	390	Pl.
18	U.C.	146	375	El.
19	C.U.F.	175	360	El.
7	C	115	355	Pl.
4	U	116	320	Pl.
6	U	115	280	El.
38	Z	175	280	El.
17	F.C.	147	275	El.
43	$MgSO_4$	175	185	Pl.
39	Z	175	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE XI

SPECIMENS 24 HOURS IN FORMS 20 DAYS IN WATER
THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN.

Test No.	Chemical Admixture	Age days	Breaking stress psi.	Condition of setting
12	Pl	129	920	El.
3	Pl	116	870	Pl.
42	S.F.	175	860	Pl.
13	Pl	129	760	Pl.
41	S.U.	175	760	Pl.
36	S	175	725	Pl.
46	S.C.	175	705	Pl.
48	$NaSiO_2$	175	690	Pl.
44	Spec	175	637	Pl.
15	F	148	578	El.
6	U	115	570	El.
14	C.U.F.	149	470	Pl.
7	C	115	455	Pl.
9	C	120	440	El.
10	F.C.	120	440	Pl.
11	U.C.	129	410	Pl.
18	U.C.	146	400	El.
2	Pl	116	400	El.
16	U.F.	147	390	El.
45	NaO	175	360	Pl.
5	F	116	330	Pl.
4	U	116	310	Pl.
8	U.F.	121	270	Pl.
43	$MgSO_4$	175	260	Pl.
19	C.U.F.	175	240	El.
38	Z	175	230	El.
17	F.C.	147	210	El.
39	Z	175	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE XII

SPECIMENS 24 HOURS IN FORMS 27 DAYS IN WATER
THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN.

Test No.	Chemical Admixture	Age days	Breaking stress psi.	Condition of setting
44	Spec	175	1000	Pl.
42	S.F.	175	880	Pl.
46	S.C.	175	815	Pl.
36	S	175	775	Pl.
48	$NaSiO_2$	175	770	Pl.
3	Pl	116	740	Pl.
41	S.U.	175	715	Pl.
18	U.C.	146	545	El.
15	F	148	530	El.
19	C.U.F.	175	530	El.
12	Pl.	129	520	El.
9	C	120	470	El.
45	NaO	175	460	Pl.
13	Pl	129	430	Pl.
5	F	116	410	Pl.
16	U.F.	147	410	El.
38	Z	175	410	El.
14	C.U.F.	149	380	Pl.
7	C	115	360	Pl.
10	F.C.	120	350	Pl.
2	Pl	116	344	El.
4	U	116	330	Pl.
11	U.C.	129	320	Pl.
43	$MgSO_4$	175	305	Pl.
8	U.F.	121	260	Pl.
17	F.C.	147	260	El.
6	U	115	250	El.
39	Z	175	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE XIII

SPECIMENS 24 HOURS IN FORMS, 6 DAYS IN LAB. AIR, 21 DAYS IN WATER; THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN.

Test No.	Chemical Admixture	Age days	Breaking stress psi.	Condition of setting
21	Pl	175	765	Pl.
37	S	175	750	Pl.
26	F.C.	175	590	Pl.
49	$MgSO_4$	175	575	Pl.
28	C.U.F.	175	570	Pl.
27	U.C.	175	450	Pl.
47	NaO	175	430	Pl.
24	U.F.	175	373	Pl.
25	C	147	190	Pl.
20	Pl	175	180	El.
22	U	175	177	Pl.
23	F	175	-	Pl.
40	Z	175	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE XIV

SPECIMENS 24 HOURS IN FORMS, 13 DAYS IN LAB. AIR, 14 DAYS IN WATER; THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN.

Test No.	Chemical Admixture	Age days	Breaking stress psi.	Condition of setting
21	Pl	175	890	Pl.
23	F	175	870	Pl.
49	$MgSO_4$	175	708	Pl.
37	S	175	610	Pl.
47	NaO	175	590	Pl.
22	U	175	390	Pl.
24	U.F.	175	373	Pl.
28	C.U.F.	175	370	Pl.
27	U.C.	175	275	Pl.
26	F.C.	175	270	Pl.
20	Pl	175	270	El.
25	C	147	210	Pl.
40	Z	175	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE XV

SPECIMENS 24 HOURS IN FORMS, 20 DAYS IN LAB. AIR, 7 DAYS IN WATER; THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN.

Test No.	Chemical Admixture	Age days	Breaking stress psi.	Condition of setting
24	U.F.	175	970	Pl.
49	$MgSO_4$	175	858	Pl.
37	S	175	530	Pl.
27	U.C.	175	530	Pl.
26	F.C.	175	520	Pl.
47	NaO	175	480	Pl.
22	U	175	450	Pl.
21	Pl	175	410	Pl.
23	F	175	355	Pl.
20	Pl	175	300	El.
25	C	147	270	Pl.
28	C.U.F.	175	180	Pl.
40	Z	175	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE XVI

SPECIMENS 24 HOURS IN FORMS, 27 DAYS IN LAB. AIR, 7 DAYS IN WATER; THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN.

Test No.	Chemical Admixture	Age days	Breaking stress psi.	Condition of setting
21	Pl	175	1660	Pl.
23	F	175	1180	Pl.
24	U.F.	175	1070	Pl.
27	C.U.	175	940	Pl.
26	F.C.	175	820	Pl.
47	NaO	175	620	Pl.
49	$MgSO_4$	175	610	Pl.
28	C.U.F.	175	590	Pl.
22	U	175	560	Pl.
37	S	175	550	Pl.
20	Pl	175	390	El.
25	C	147	370	Pl.
40	S	175	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

TABLE XVII

SPECIMENS 24 HOURS IN FORMS
THEN IN LAB. AIR UNTIL TESTED AT AGE SHOWN

Test No.	Chemical Admixture	Age days	Breaking Stress psi.					Condition of setting
27	C.U.	175	1260	1125	1200	1030	1155	Pl.
21	Pl	175	1000	720	1160	940	960	Pl.
26	F.C.	175	760	820	1100	870	890	Pl.
28	C.U.F.	175	610	-	-	1100	855	Pl.
25	C	147	520	950	1080	860	850	Pl.
22	U	175	640	930	1030	810	850	Pl.
49	$MgSO_4$	175	956	646	770	770	785	Pl.
23	F	175	340	710	1025	690	690	Pl.
24	U.F.	175	870	1040	-	630	635	Pl.
20	Pl	175	660	530	640	680	630	El.
47	NaO	175	660	690	530	620	625	Pl.
37	S	175	400	440	410	350	400	Pl.
40	Z	175	-	-	-	-	-	Pl.

Nomenclature

U	Urea
Pl	Plain
C	Phenol
F	Formaldahyde
Spec.	Special
Z	Phosphorus Pentoxide
S	Sand
El	Electric

DISCUSSION

The tests were, in the most part, made with neat cement. The improvement of the cement being attained, a study of the concrete with the improved cement would follow. The criticism of such a procedure is that it is not standard and that it gives irrational results. I concede that the results are not too good to compare with results obtained by others, but as it was not my objective to compare results with those of others, but to compare the results of various mixes and procedures as made by myself, I am satisfied that the results are sufficiently consistent to form an opinion.

Let me point out that although the standard tests on concrete and mortars make use of a test specimen that has been cured in water for the full period of aging, in the construction of buildings we seldom cure our concrete over three days. It has been my objective here to try to duplicate to some degree what happens in the field and to find out if under these conditions certain admixtures would increase the strength of my cement paste.

A study of the results shows that after seven days (one day in forms, six days in water) urea, phenol, formaldahyde, sodium oxide and sodium silicate did not lower the strength of the cement paste; that after fourteen days (one day in forms, thirteen days in water) urea, formaldahyde and phenol, by themselves and in combination, show an average better than plain cement while sodium oxide, magnesium sulphate and sodium silicate are on a par with plain cement; that after twenty-one days (one day in forms, thirteen days in water) urea, formaldahyde, phenol, magnesium sulphate and sodium silicate and combinations of urea, phenol and formaldahyde are still on a par with plain cement; that after twenty-eight days (one day in forms, twenty-six days in water) urea, formaldahyde, phenol and combinations thereof are still holding their own with plain cement. Looking now at the specimens that were withdrawn from the water and placed in laboratory air at periods of time parallel to above stated test times and tested at an average age of five months, we find for seven days water curing that urea, formaldahyde, phenol and combinations thereof and sodium silicate are still comparable with plain cement; for fourteen days curing tested at five months, no comparative changes; for twenty-one days curing tested at five months, no comparative changes; and for twenty-eight days curing tested at five months, no comparative changes. The samples of cement mortars with urea, formaldahyde and phenol admixtures treated as above show a general increase of about ten percent (10%) in strength over plain cement mortars throughout the testing period.

A study of the specimens left to cure in the laboratory air shows for seven day test an average increase in strength of about ten percent (10%) for urea, formaldahyde, phenol and combinations of these and magnesium sulphate over the average for plain cement. For fourteen day test these same admixtures are on a par or a little below that of plain cement. For twenty-one day test, except for phenol-urea, these admixtures are on a par with plain cement, but phenol-urea shows a fifty percent (50%) increase over the plain cement average. For twenty-eight day test the urea admixture has gained twenty percent (20%) over the plain, the phenol-urea maintains about a thirty-five percent (35%) increase and the rest of the above mentioned admixtures are about on a par with the plain cement. At the end of six months urea, formaldahyde, phenol and combinations of these are all leading the plain cement, with phenol-urea about fifty percent (50%) the better.

After a study of the specimens that were air-cured then soaked in water and again left in air until tested, we find that for seven days in laboratory air, twenty-one days in water, then in laboratory air until tested at six months, the average of the urea, formaldahyde, phenol, combinations of these and magnesium sulphate were on a par with the average of plain cement. For fourteen days in laboratory air, fourteen days in water, and then in laboratory air until tested at six months, magnesium-sulphate and formaldahyde are on a par with plain cement, but the rest have fallen below. For twenty-one days in laboratory air, seven days in water, and then in labora-tory air until tested at six months, urea-formaldahyde and magnesium sulphate show one hundred percent (100%) gains over plain cement while the rest are on a par or a little better. For the twenty-eight days in laboratory air, seven days in water and then in laboratory air until tested at six months, urea-formaldahyde, urea-phenol and formaldahyde show good improvements over the average plain cement; the rest are on a par with the average, but one plain cement specimen is way ahead of the average of all (unexplainable except that the value could be in error).

CONCLUSIONS

From a study of the results as related in the discussion I conclude that: The admixture of urea, formaldahyde, phenol, combinations of these, magnesium sulphate, and sodium silicate show a tendency to improve the strength of the cement. The admixture of phenol-urea for concrete that is to be placed where present curing methods are not economical will give an increased ultimate strength. The admixture of urea, formaldahyde, phenol or combinations of these will give a more reliable cement paste; test results show that these admixtures give a more consistent result than plain cement paste. A glance at curves for test specimens eleven, eighteen and twenty-seven in comparison to others will confirm this.

RECOMMENDATIONS

I would recommend that optimum data be obtained for admixtures of urea, formaldahyde, phenol and combinations of these. The procurement of such data will take a long time, but I feel that the preliminary investigations indicate that these admixtures will, if properly applied, prove beneficial to the concrete structure.

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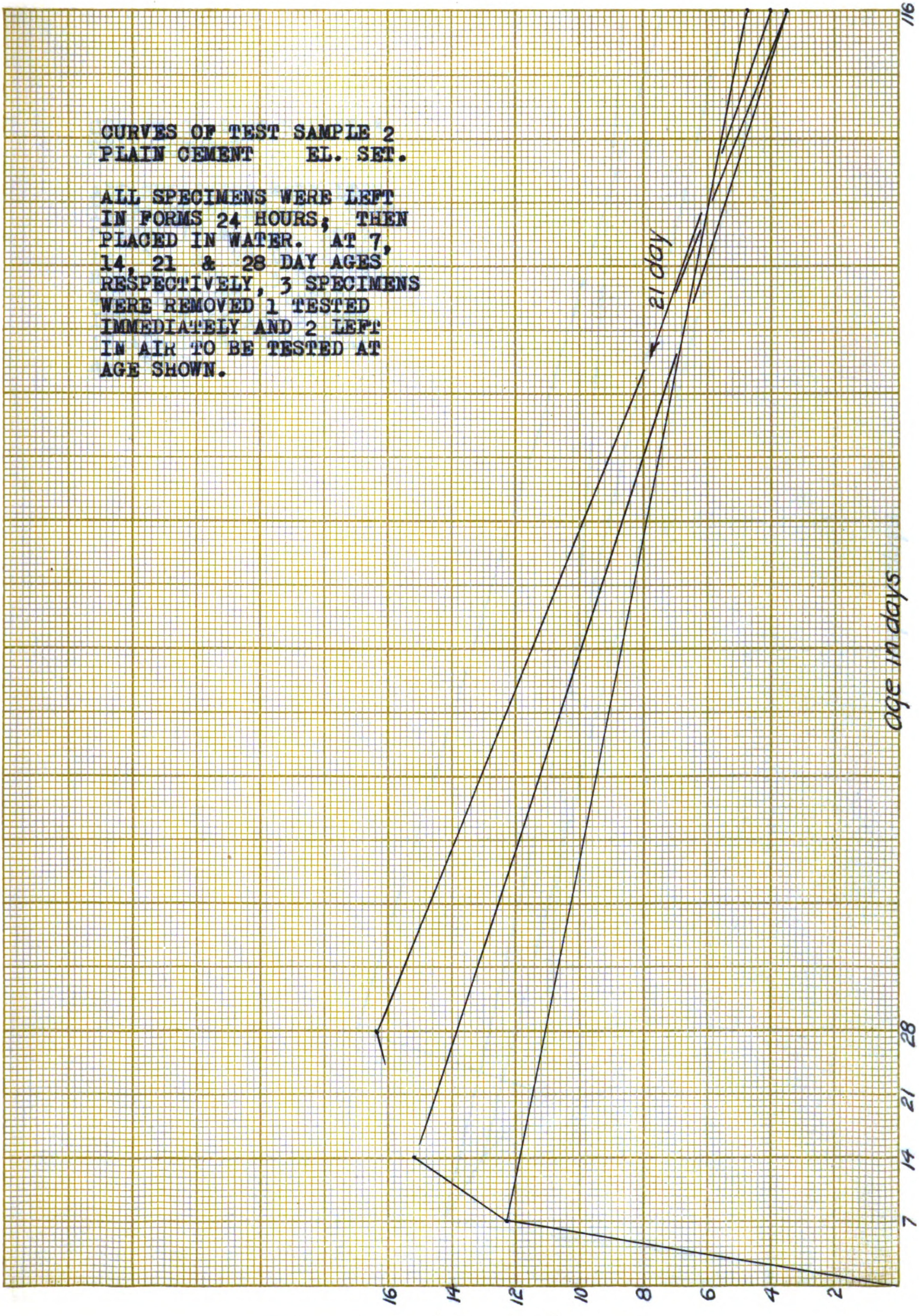
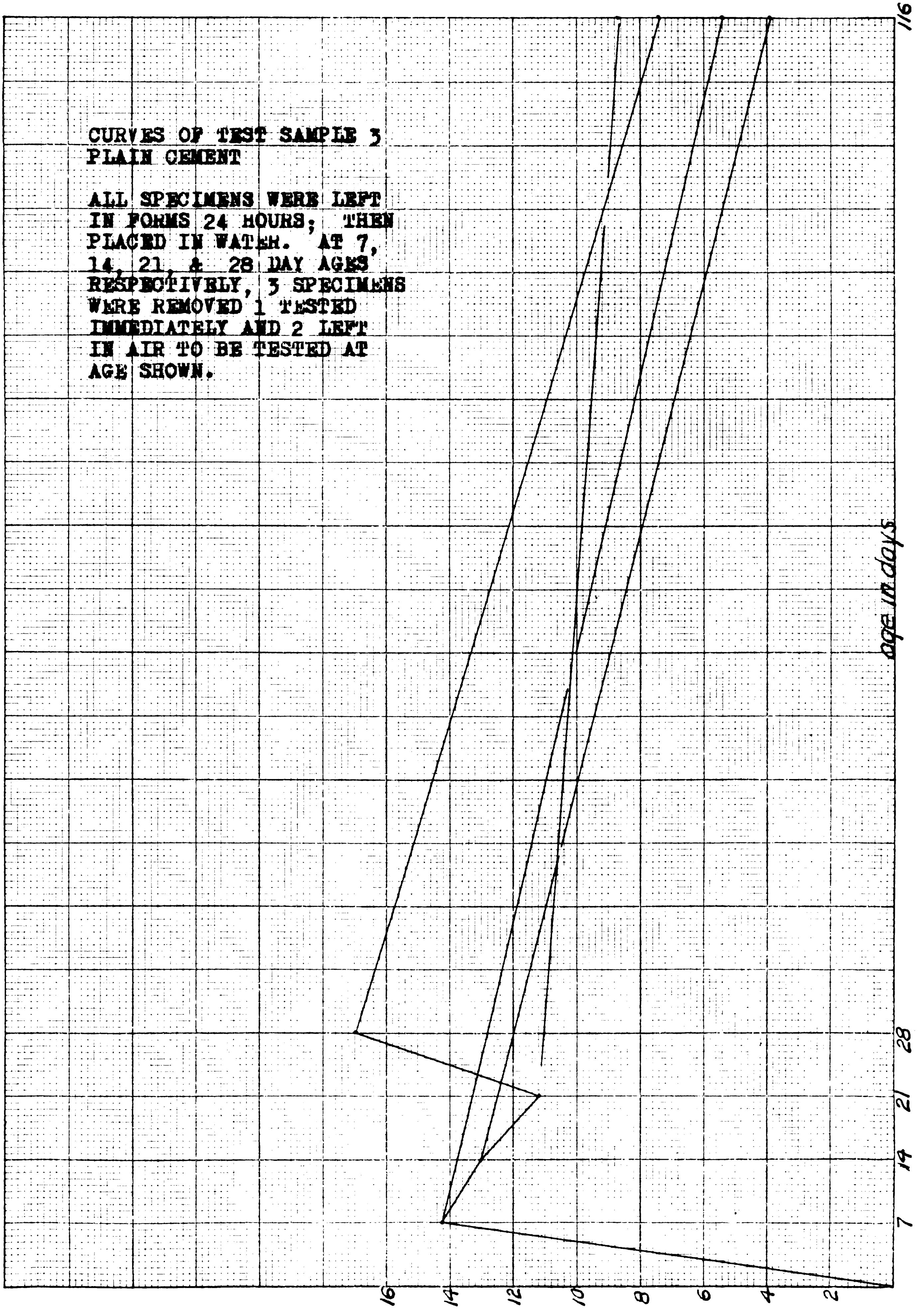


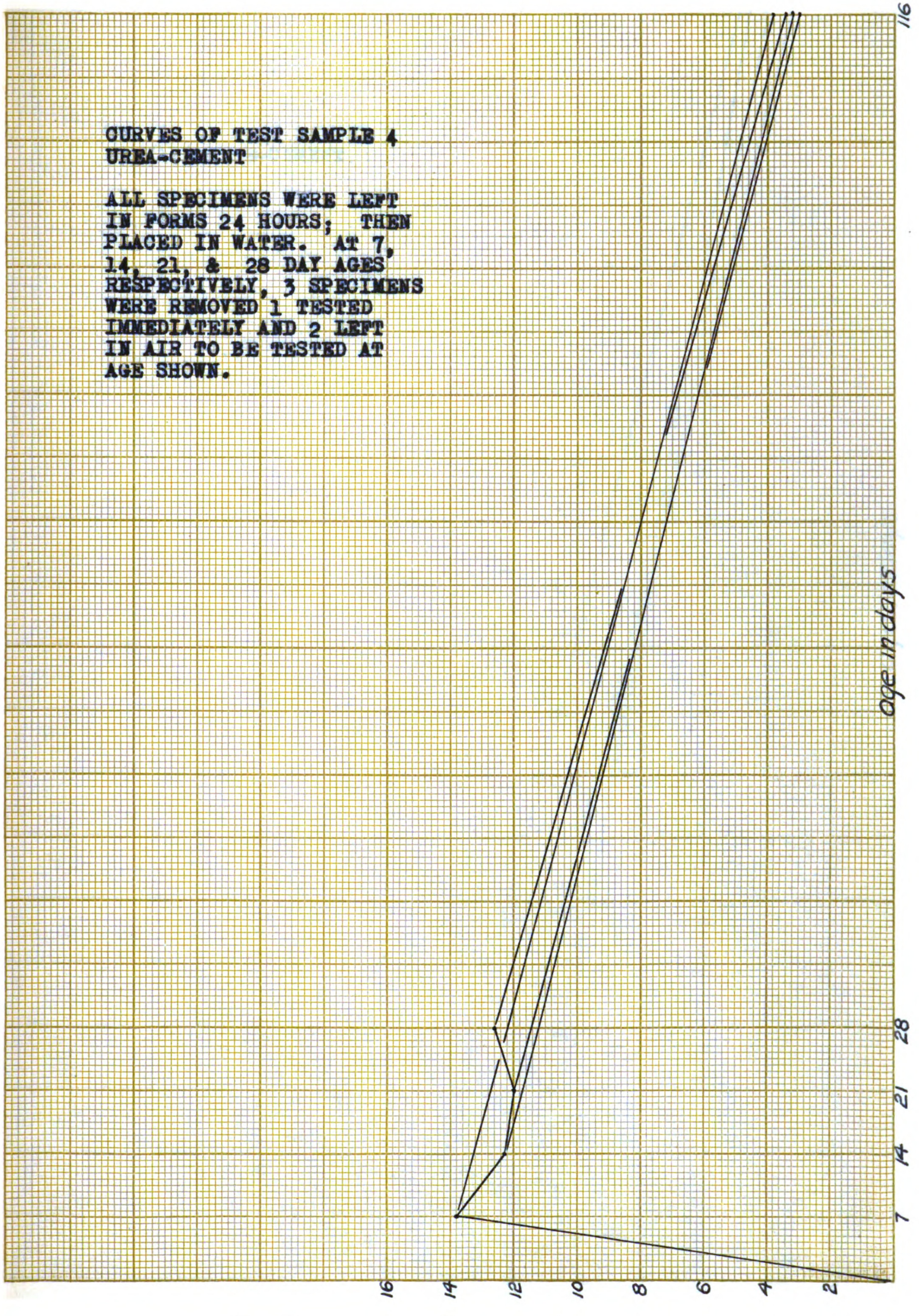
CURVES OF TEST SAMPLE 2
PLAIN CEMENT EL. SET.

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21 & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



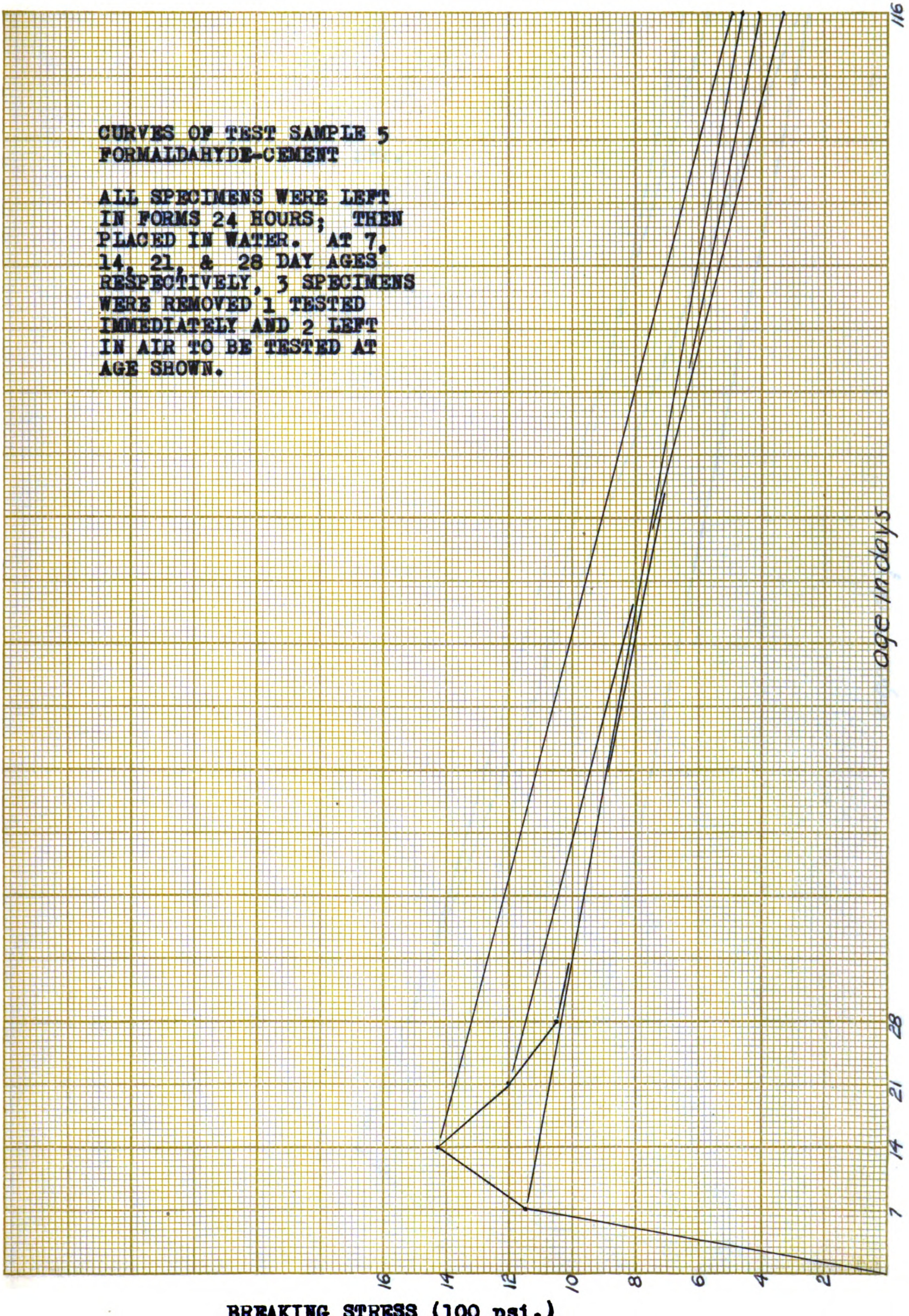
CURVES OF TEST SAMPLE 3
PLAIN CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



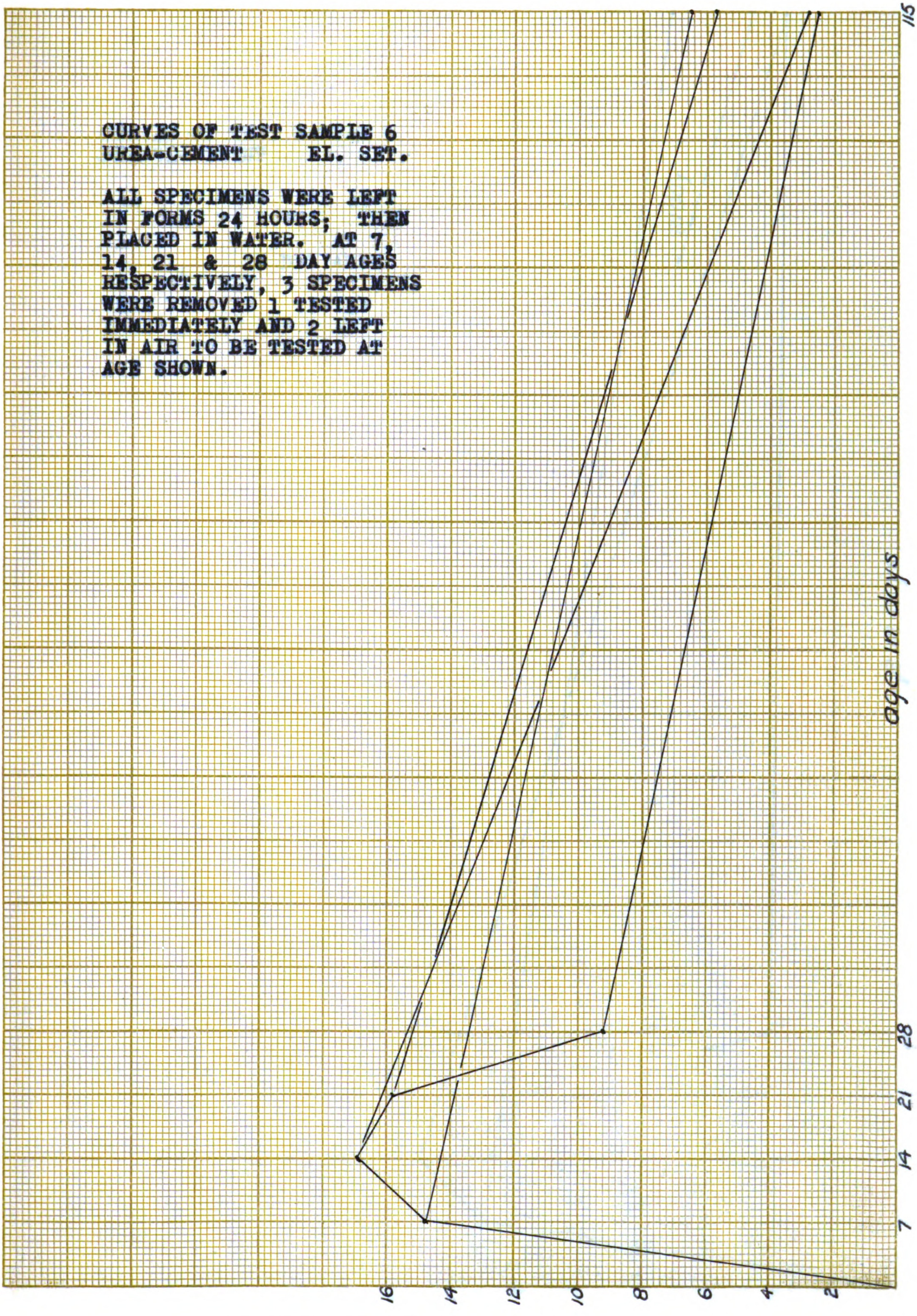
CURVES OF TEST SAMPLE 4
UREA-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



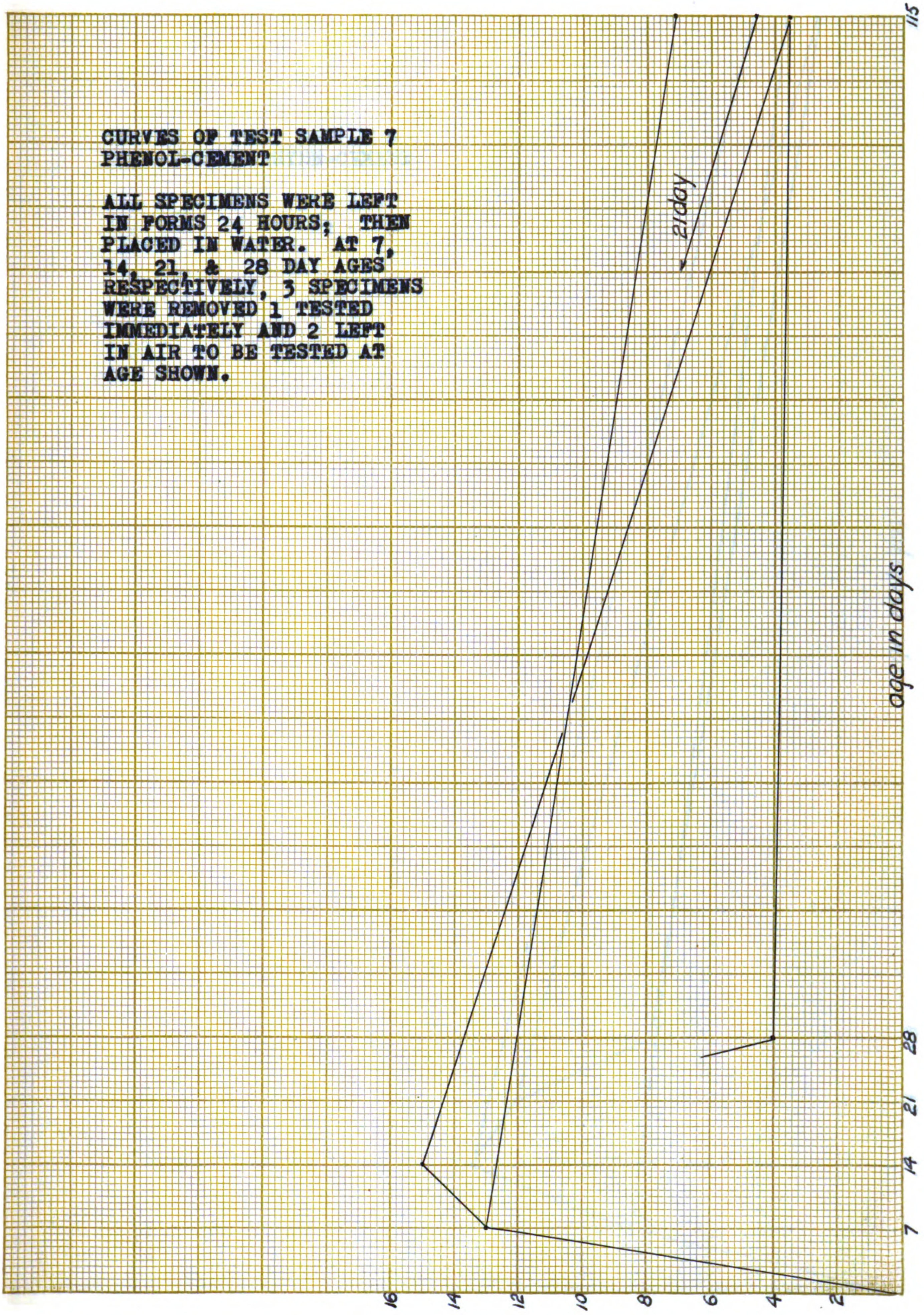
CURVES OF TEST SAMPLE 5
FORMALDAHYDE-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



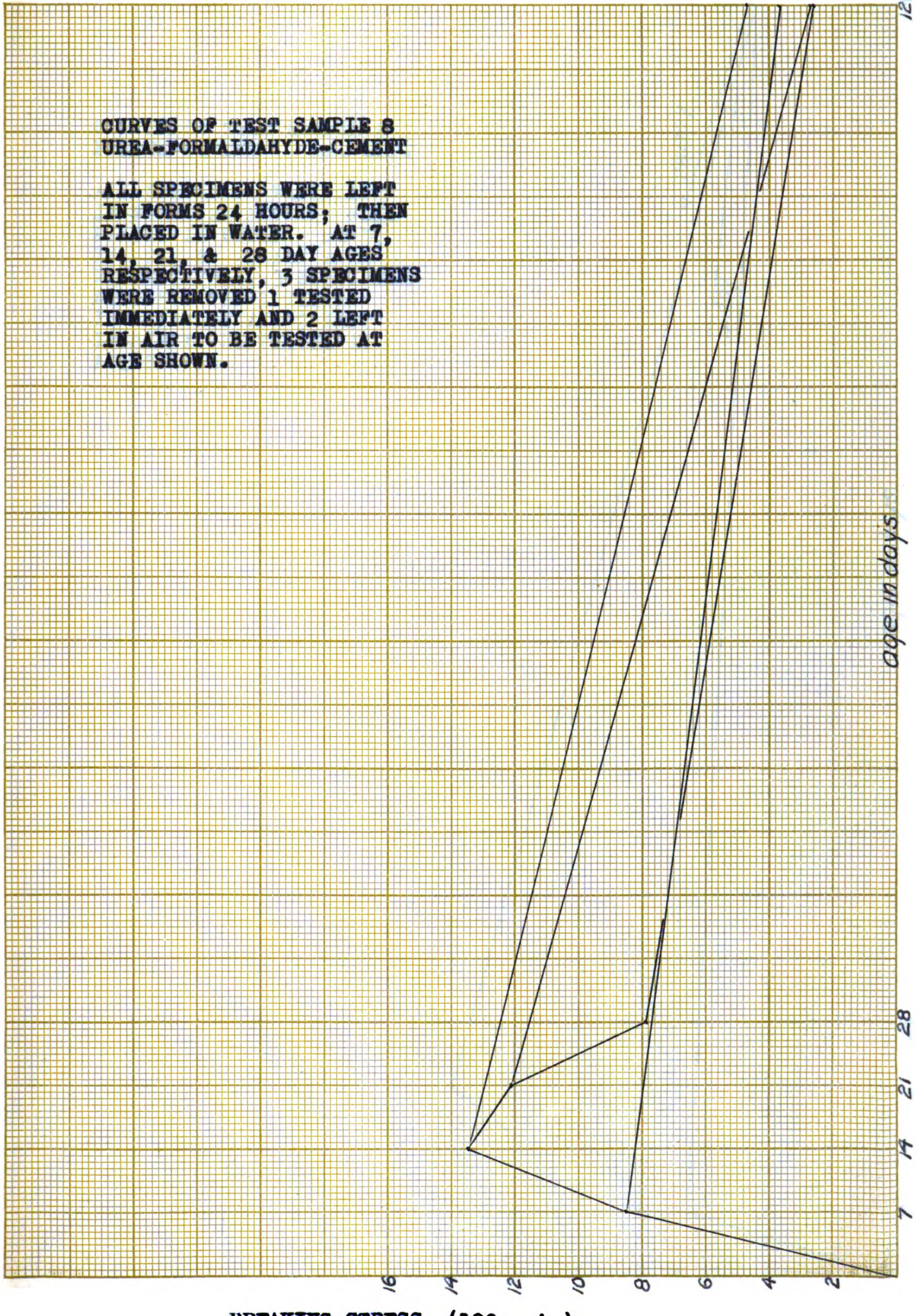
CURVES OF TEST SAMPLE 6
UREA-CEMENT EL. SET.

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21 & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



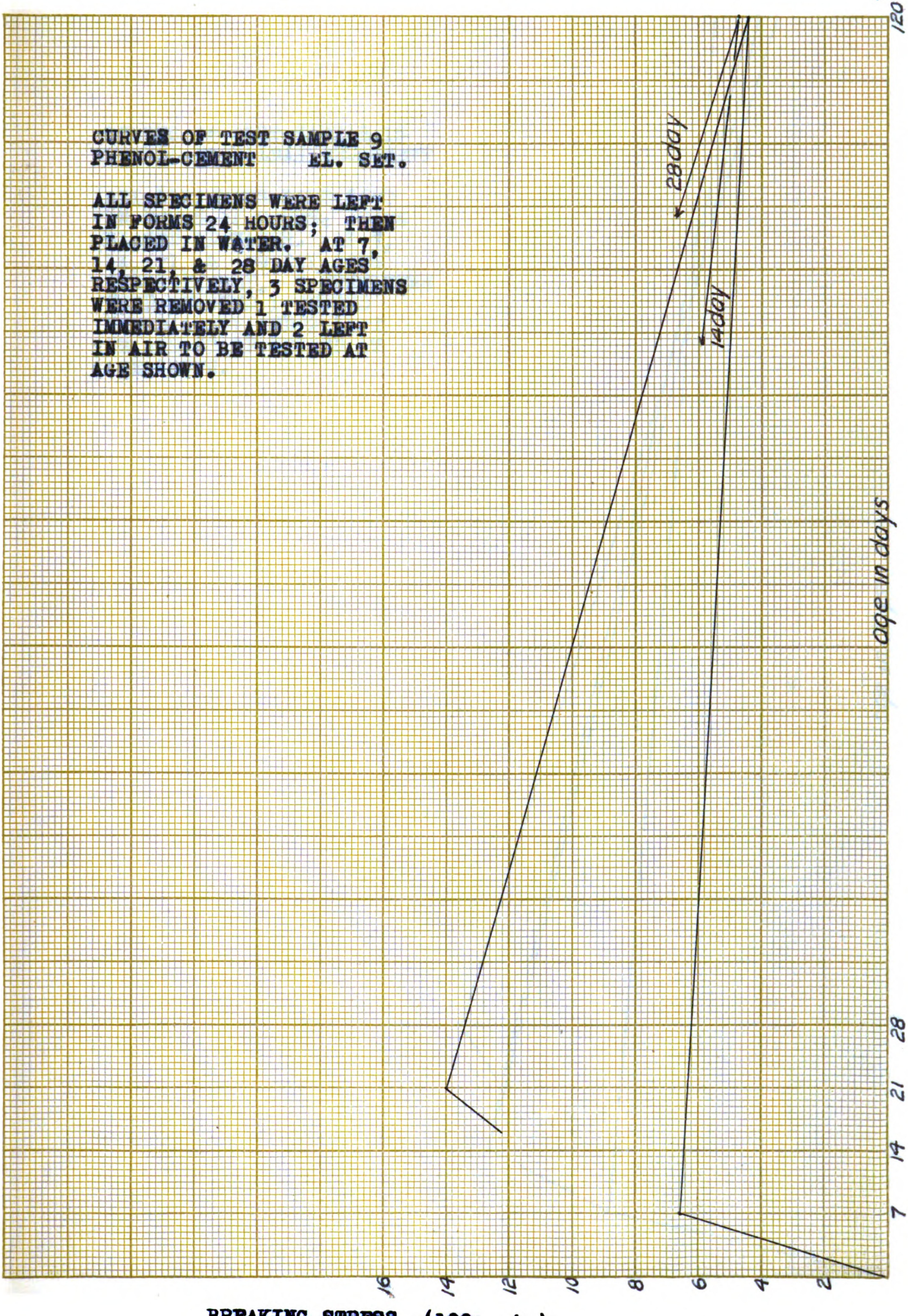
CURVES OF TEST SAMPLE 7
PHENOL-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



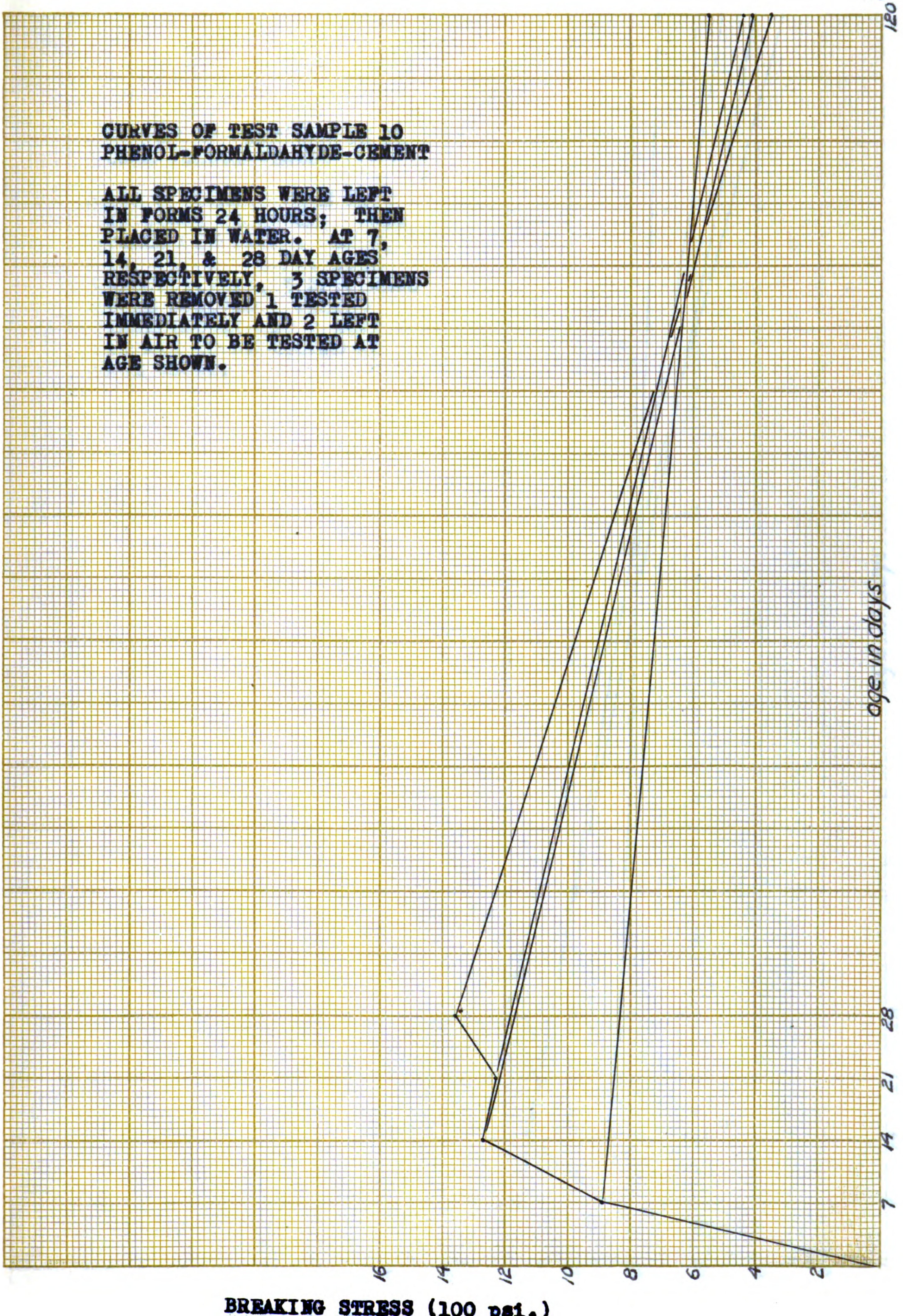
CURVES OF TEST SAMPLE 8
UREA-FORMALDAHYDE-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



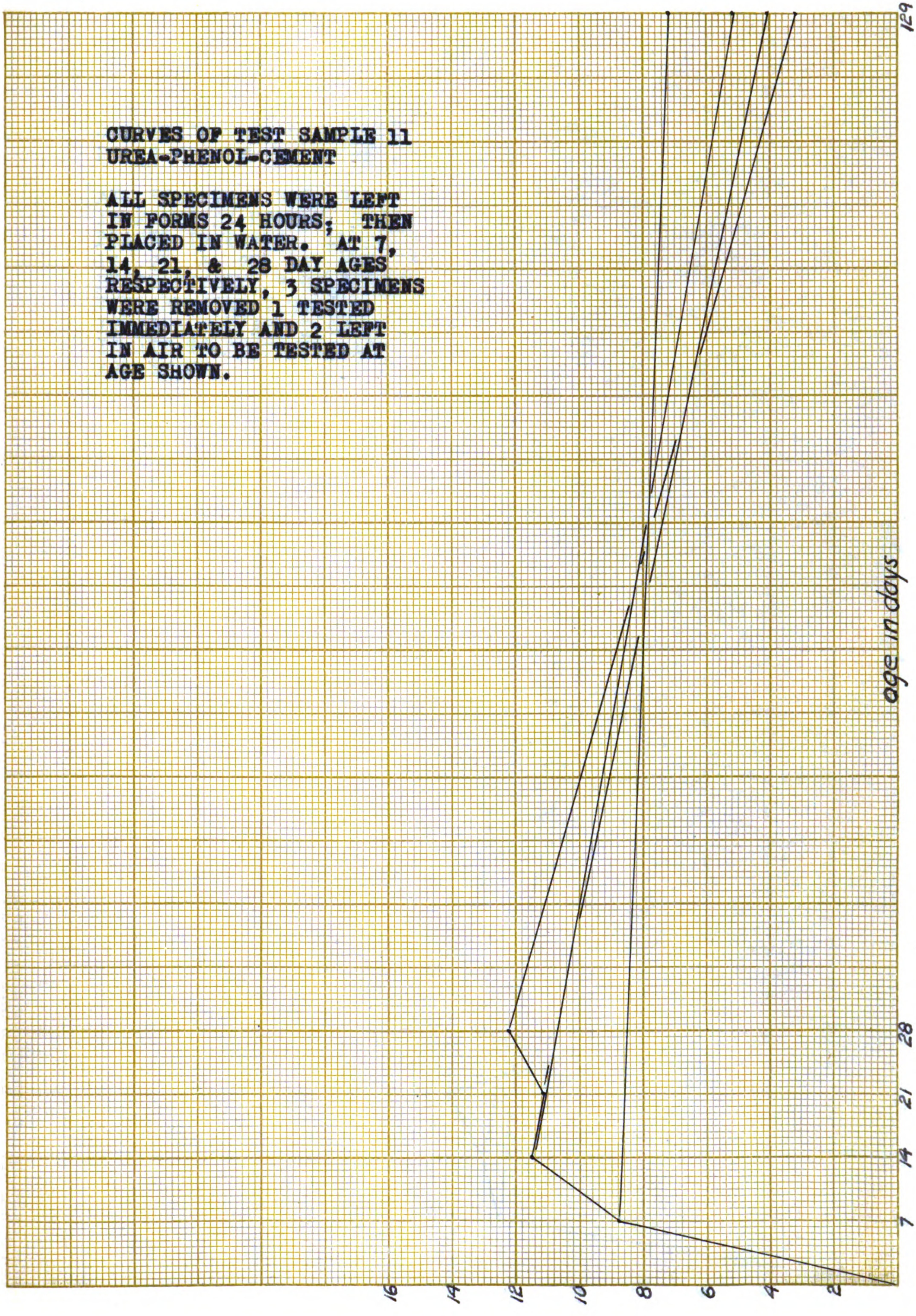
CURVES OF TEST SAMPLE 9
PHENOL-CEMENT EL. SET.

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



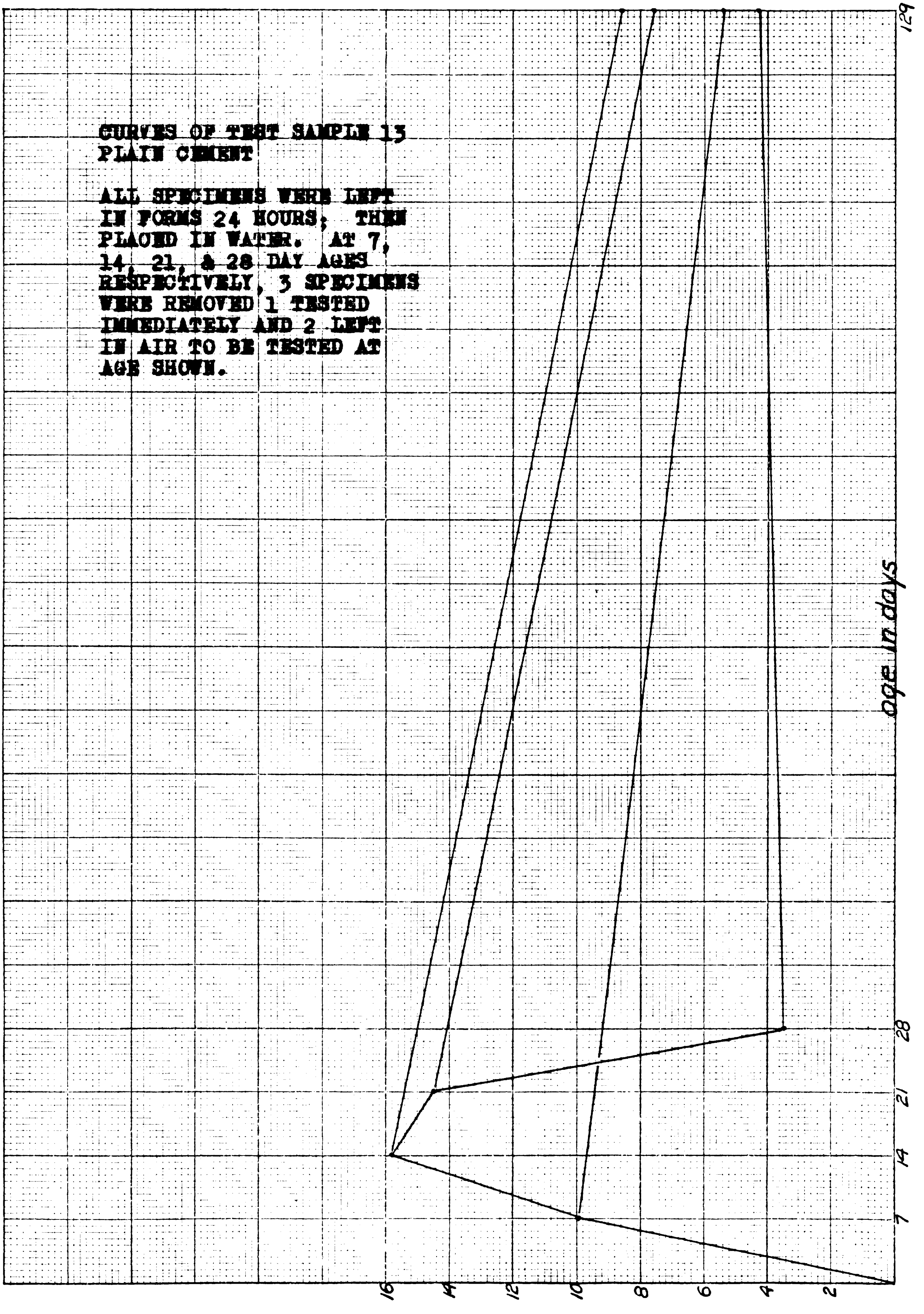
CURVES OF TEST SAMPLE 10
PHENOL-FORMALDAHYDE-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



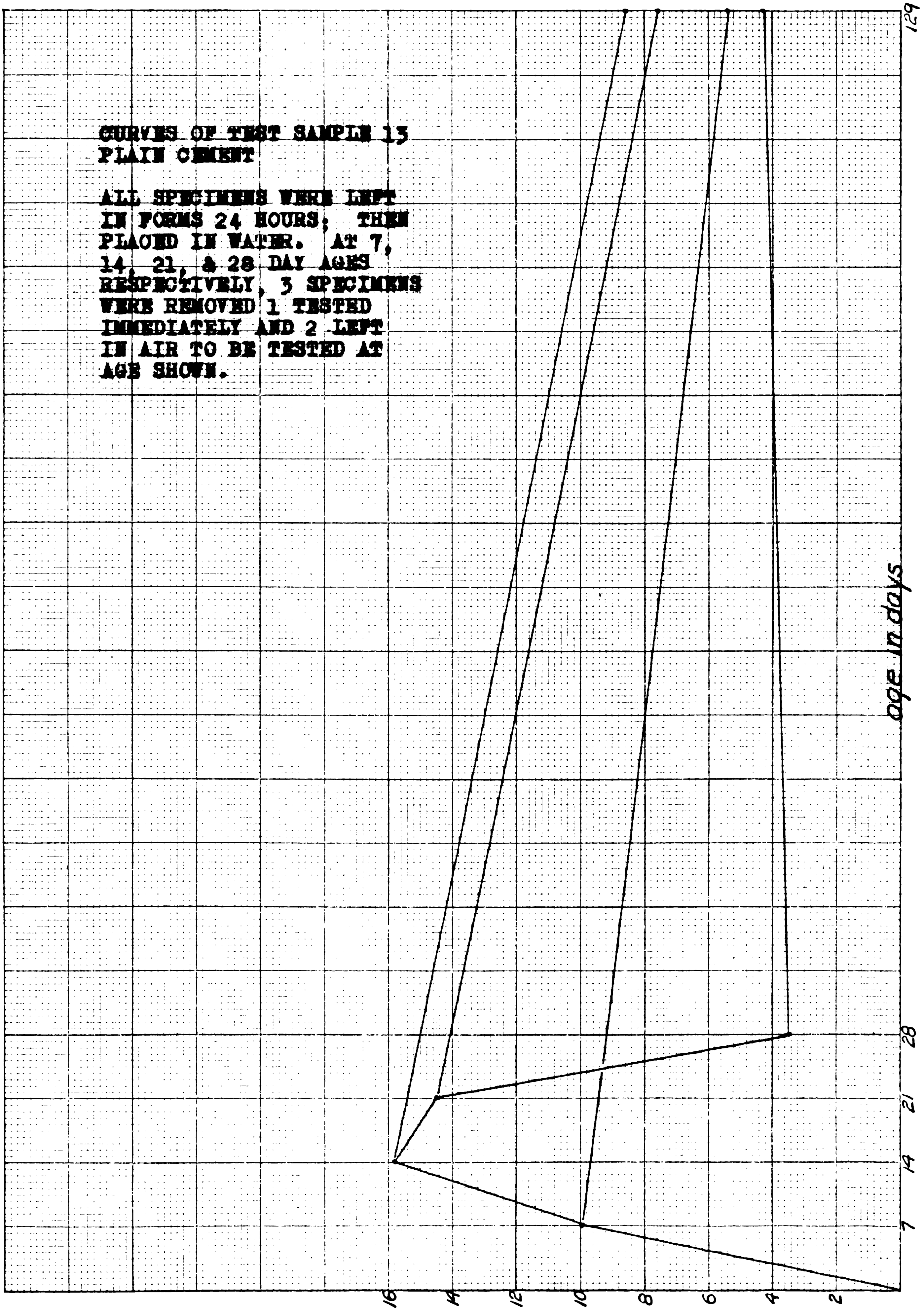
CURVES OF TEST SAMPLE 11
UREA-PHENOL-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



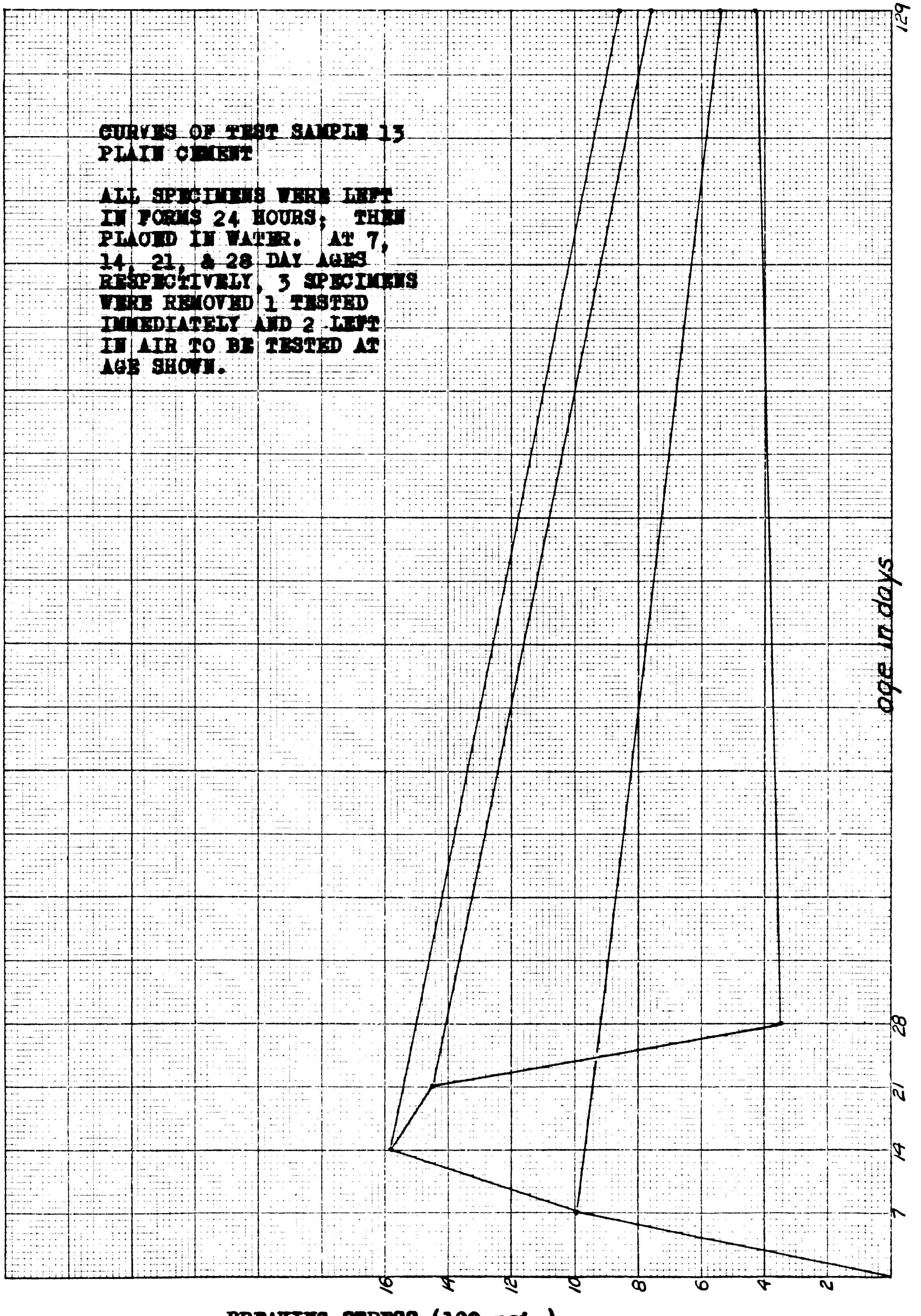
CURVES OF TEST SAMPLE 13
PLAIN CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



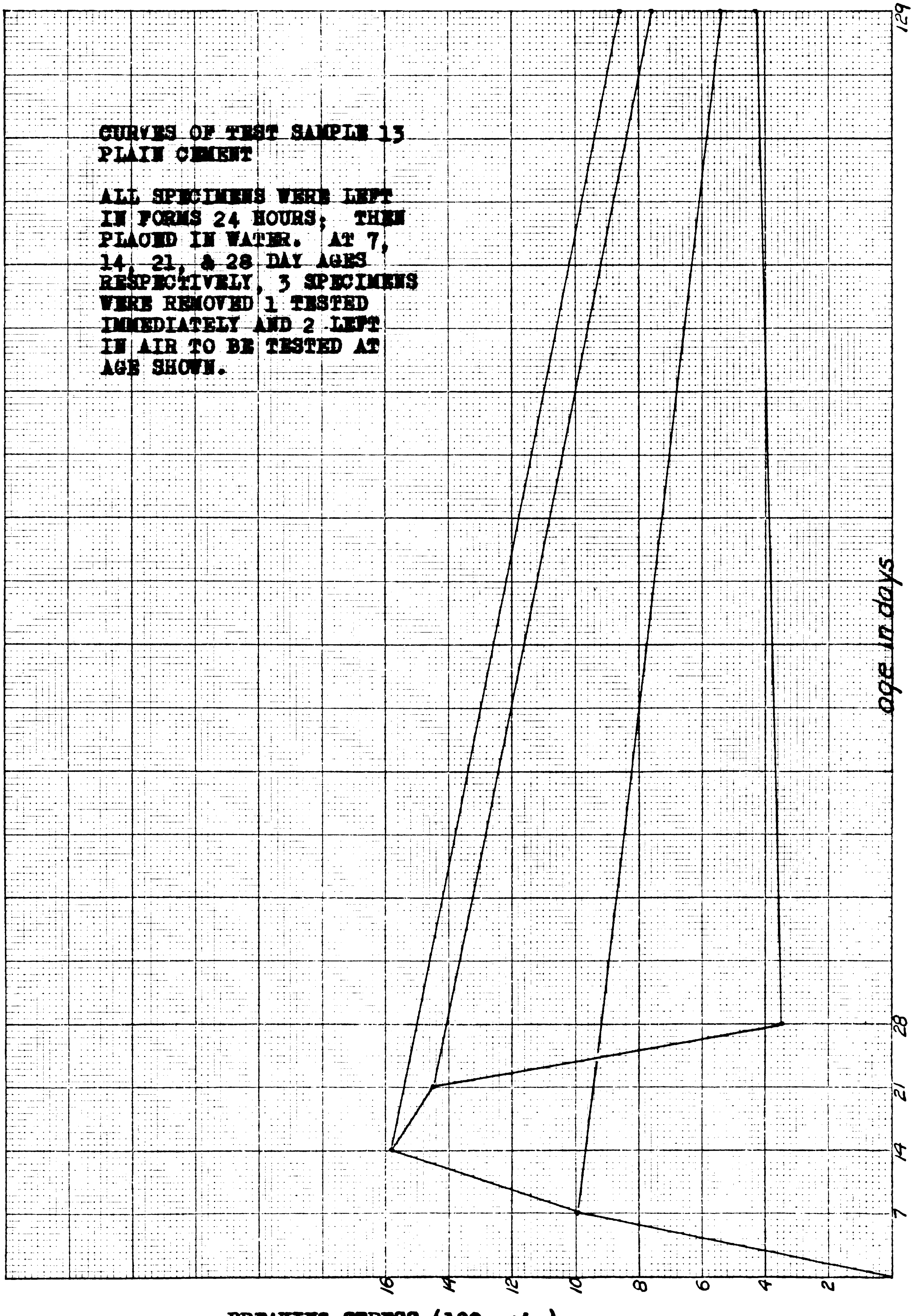
CURVES OF TEST SAMPLE 13
PLAIN CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



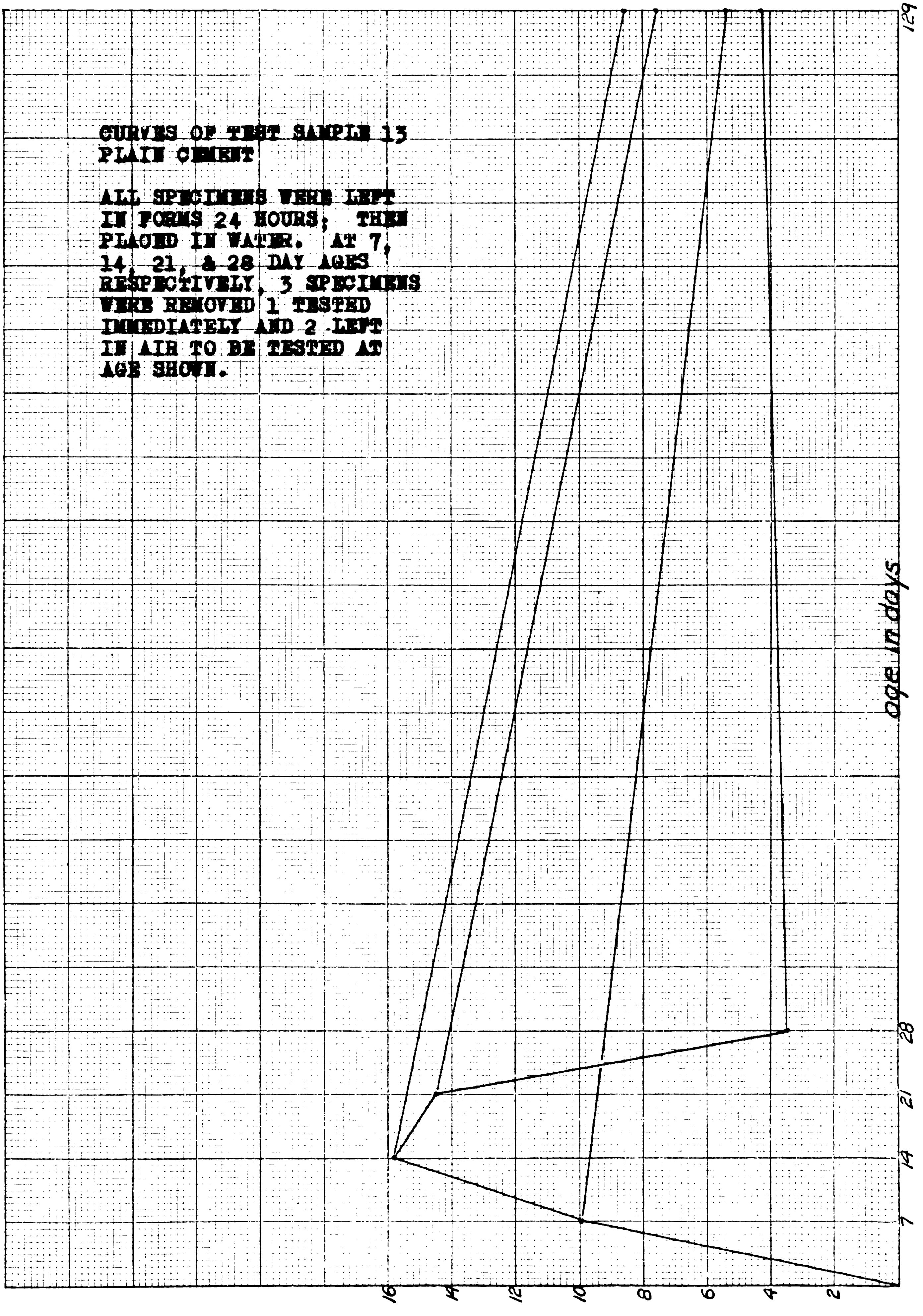
CURVES OF TEST SAMPLE 13
PLAIN CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



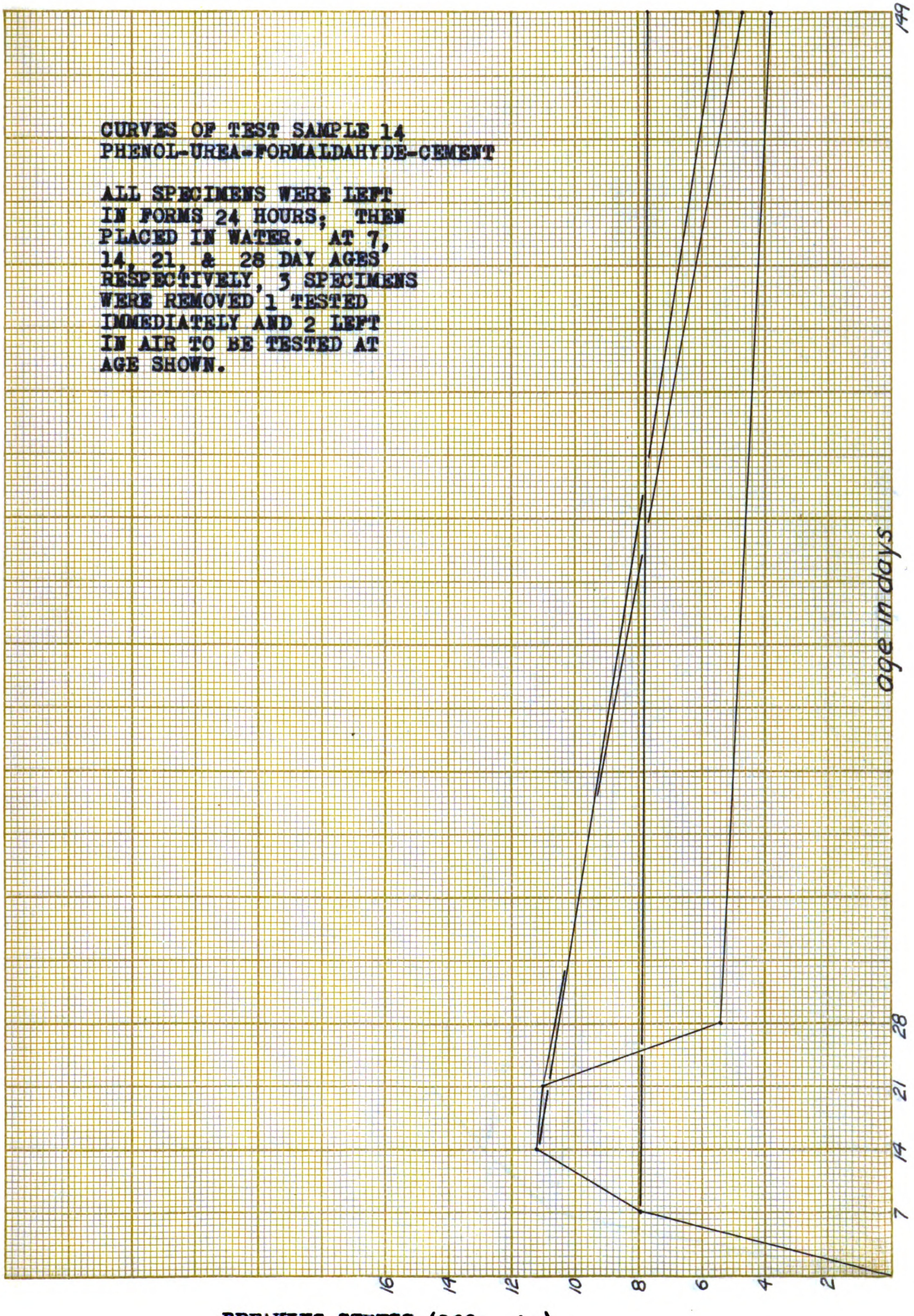
CURVES OF TEST SAMPLE 13
PLAIN CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



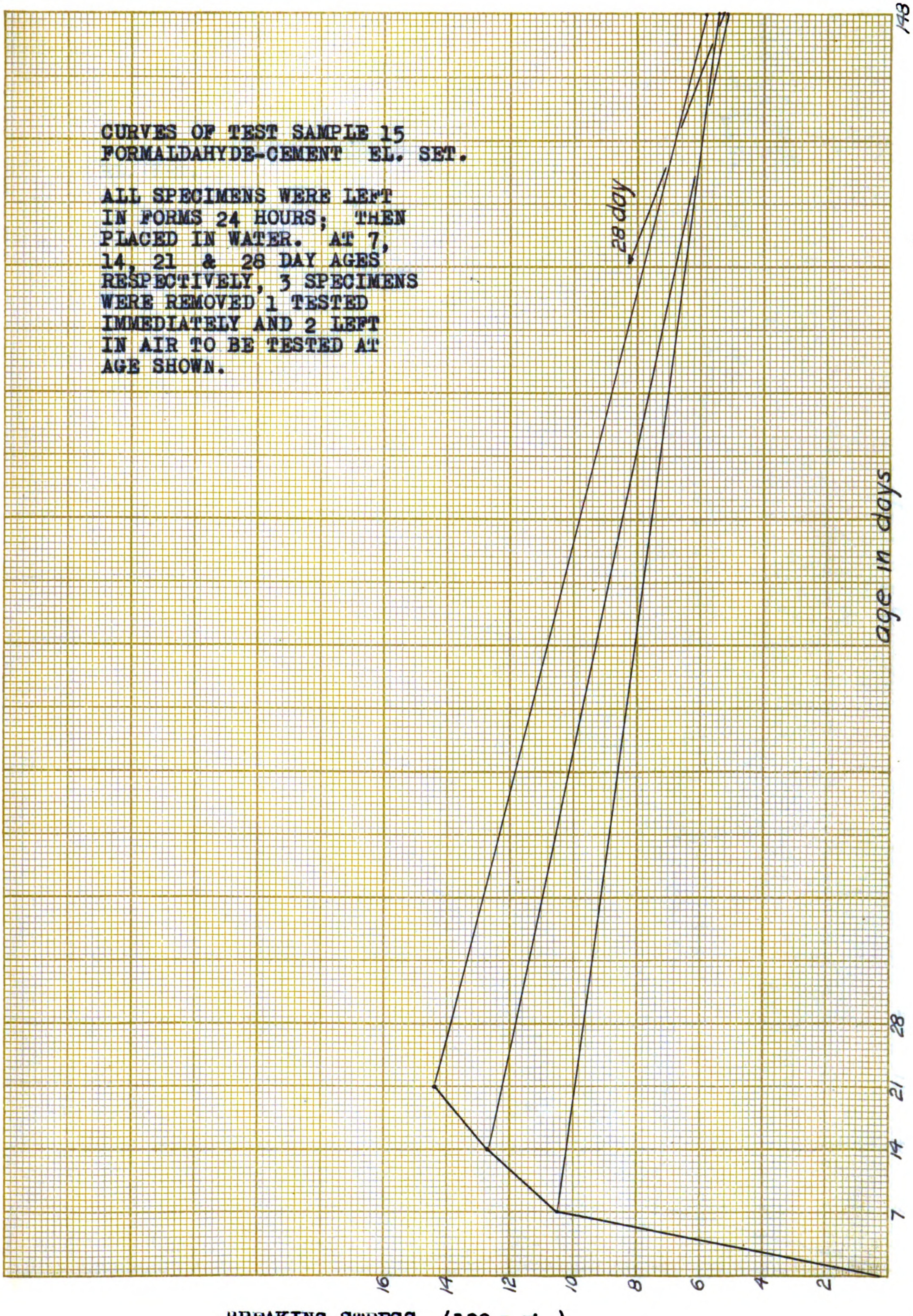
CURVES OF TEST SAMPLE 13
PLAIN CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



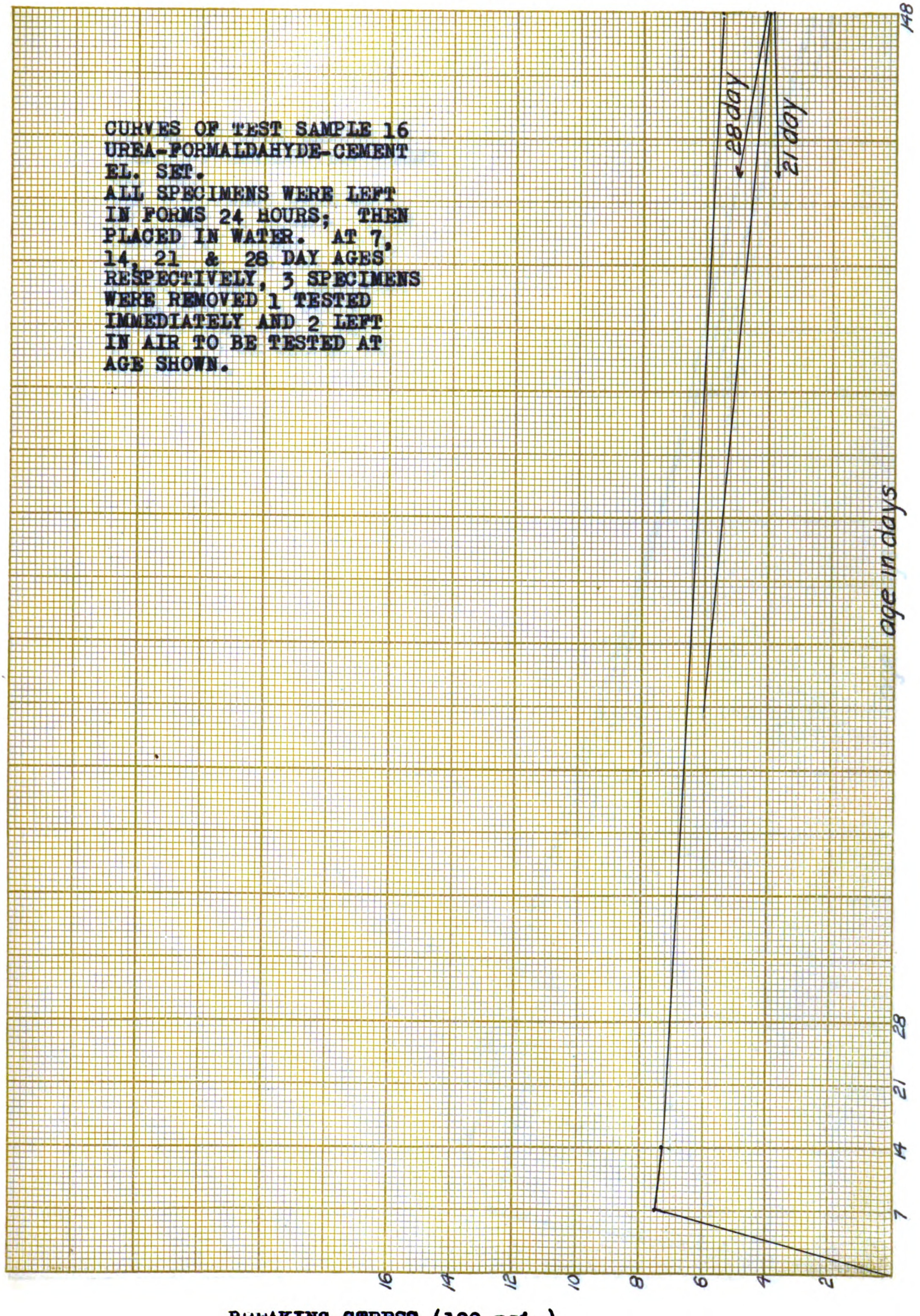
CURVES OF TEST SAMPLE 14
PHENOL-UREA-FORMALDAHYDE-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.

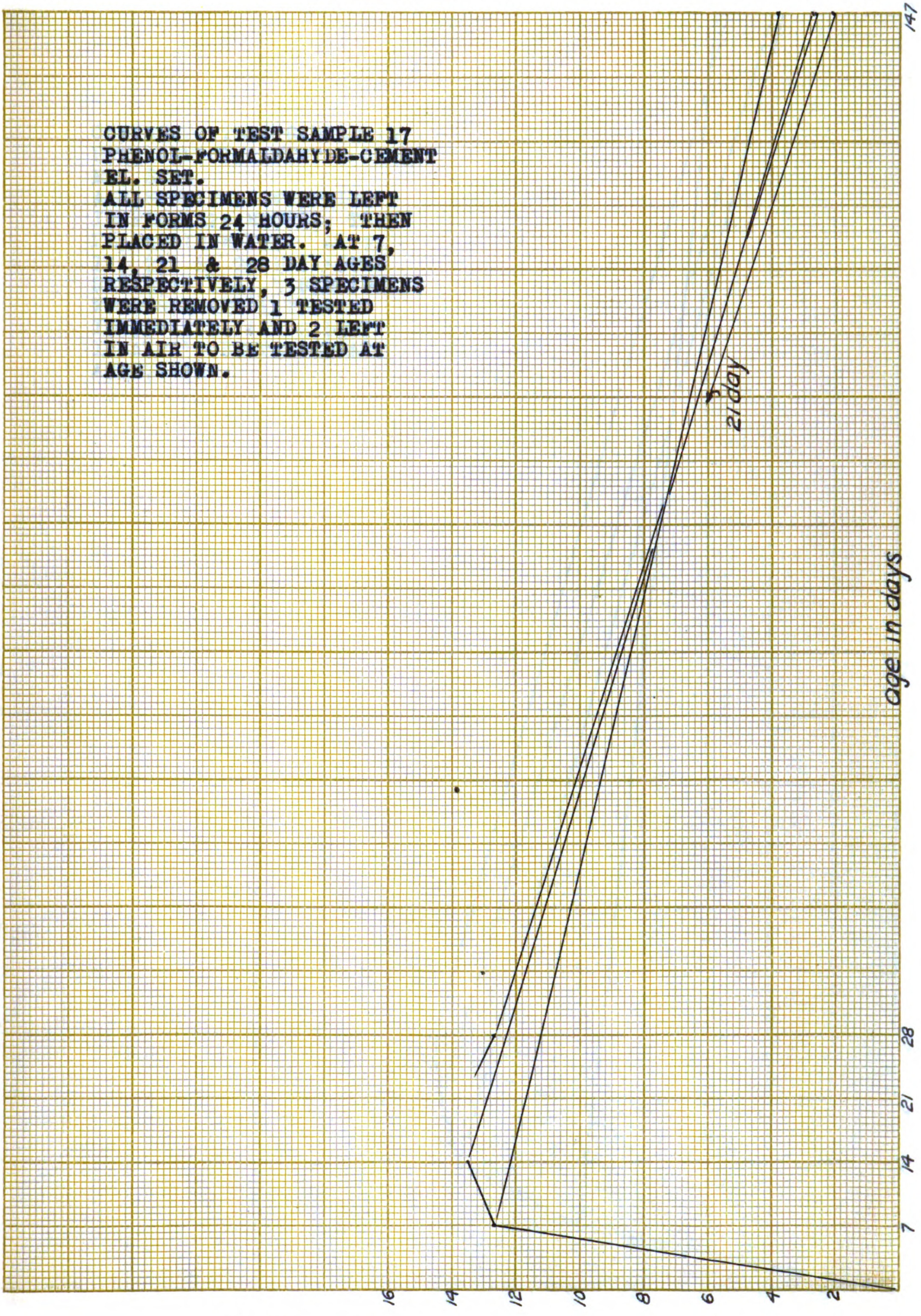


CURVES OF TEST SAMPLE 15
FORMALDAHYDE-CEMENT EL. SET.

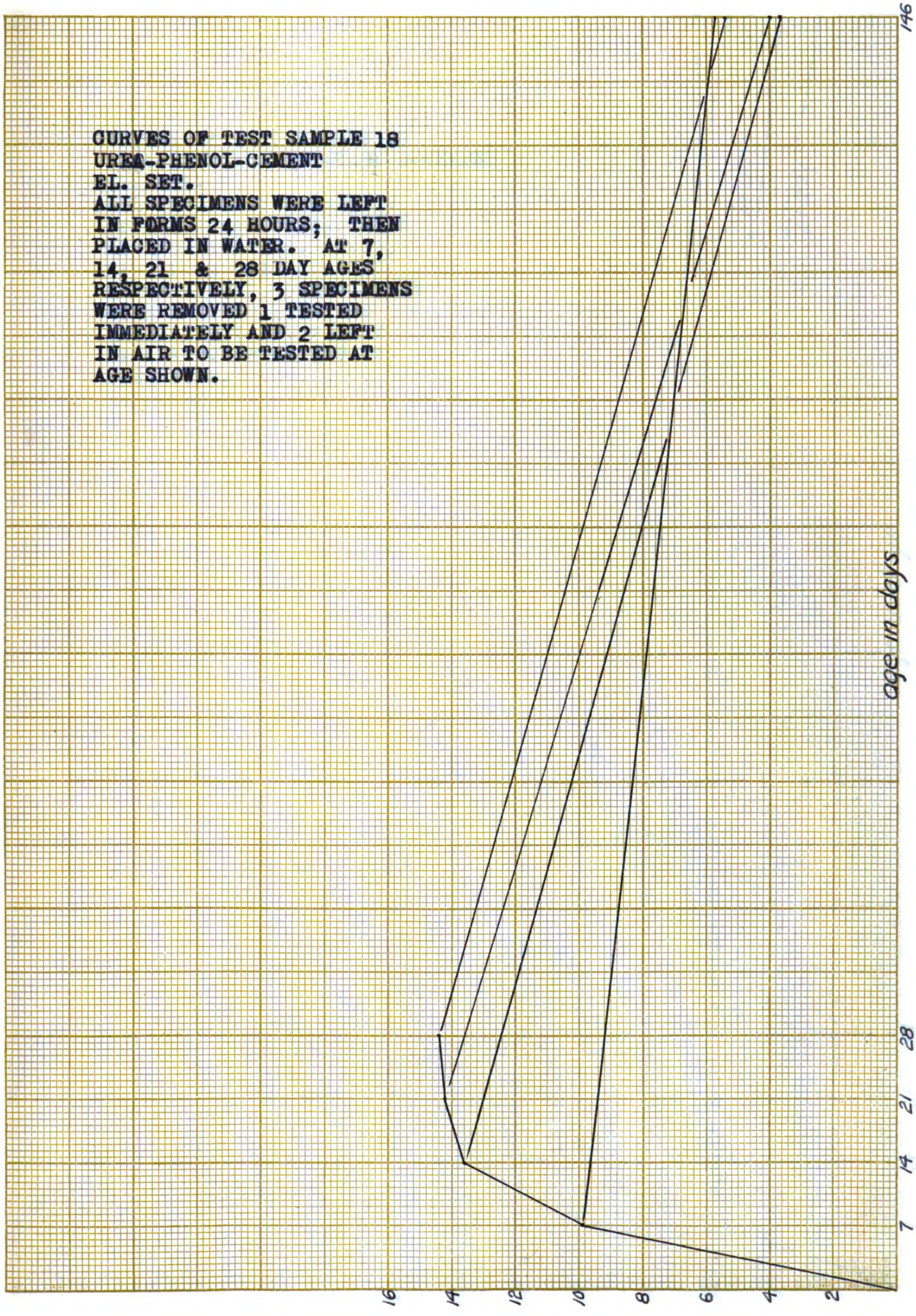
ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21 & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



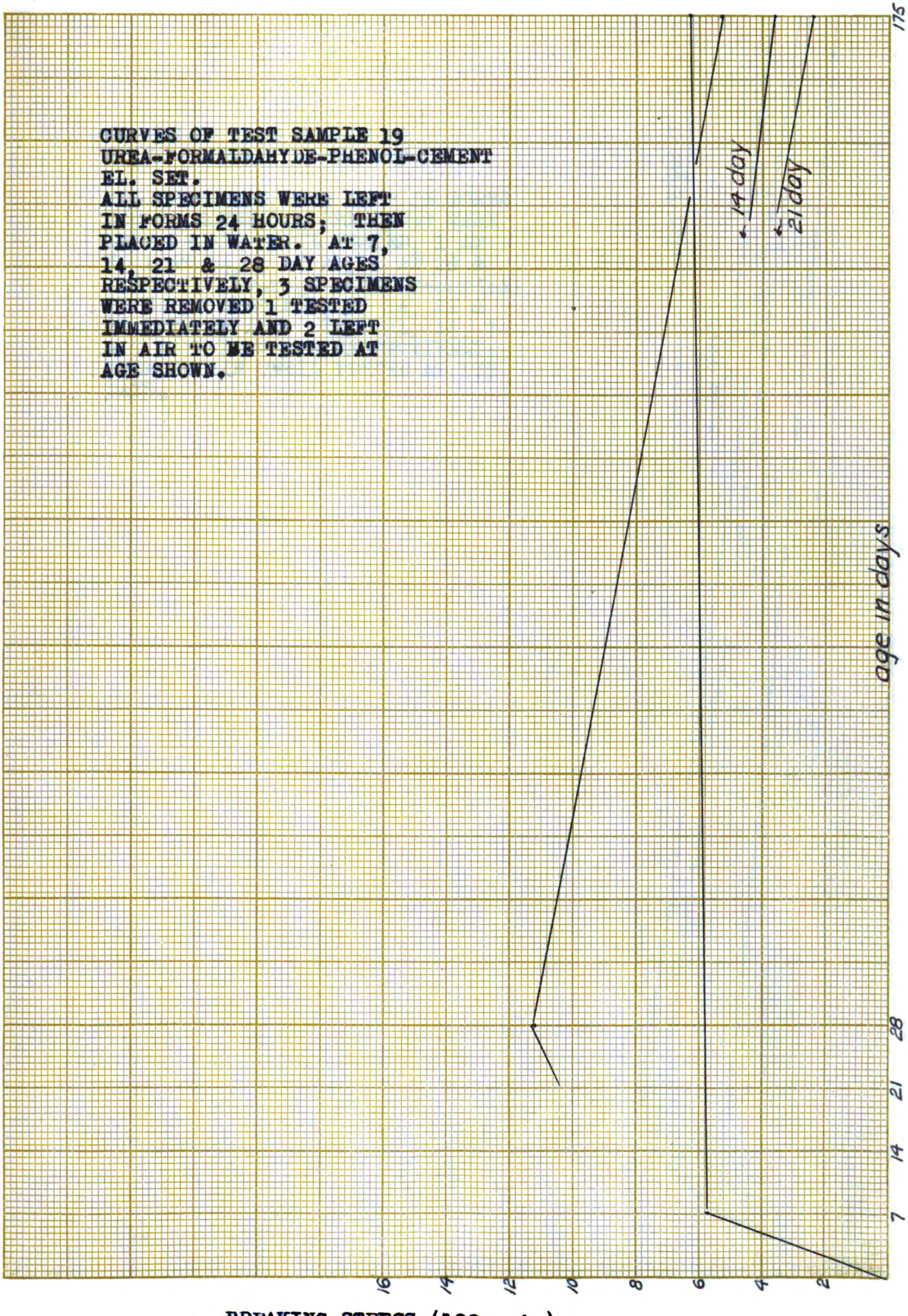
CURVES OF TEST SAMPLE 16
UREA-FORMALDAHYDE-CEMENT
EL. SET.
ALL SPECIMENS WERE LEFT
IN FORMS 24 HOURS; THEN
PLACED IN WATER. AT 7,
14, 21 & 28 DAY AGES
RESPECTIVELY, 3 SPECIMENS
WERE REMOVED 1 TESTED
IMMEDIATELY AND 2 LEFT
IN AIR TO BE TESTED AT
AGE SHOWN.



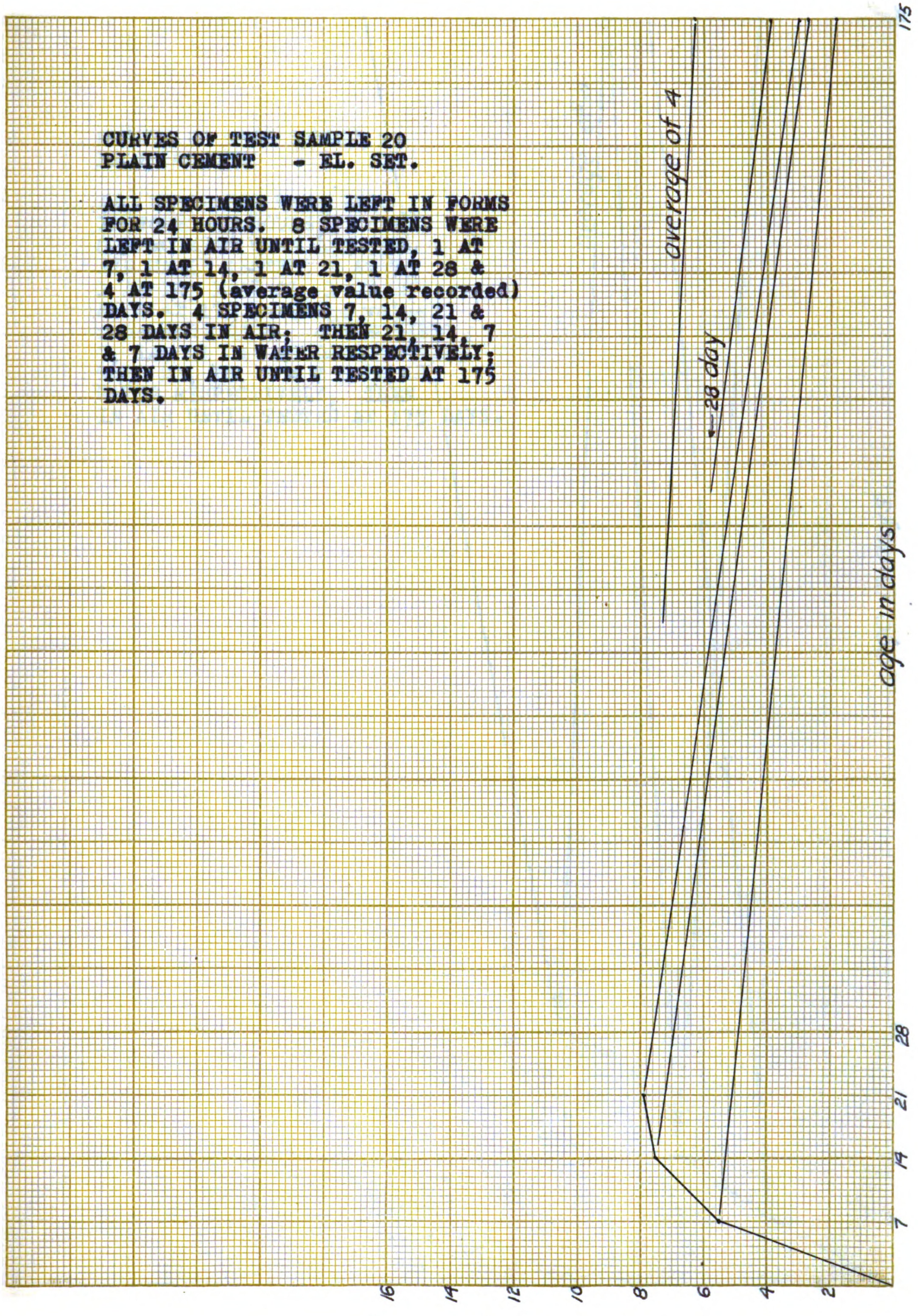
CURVES OF TEST SAMPLE 17
PHENOL-FORMALDAHYDE-CEMENT
EL. SET.
ALL SPECIMENS WERE LEFT
IN FORMS 24 HOURS; THEN
PLACED IN WATER. AT 7,
14, 21 & 28 DAY AGES
RESPECTIVELY, 3 SPECIMENS
WERE REMOVED 1 TESTED
IMMEDIATELY AND 2 LEFT
IN AIR TO BE TESTED AT
AGE SHOWN.



CURVES OF TEST SAMPLE 18
UREA-PHENOL-CEMENT
EL. SET.
ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21 & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.

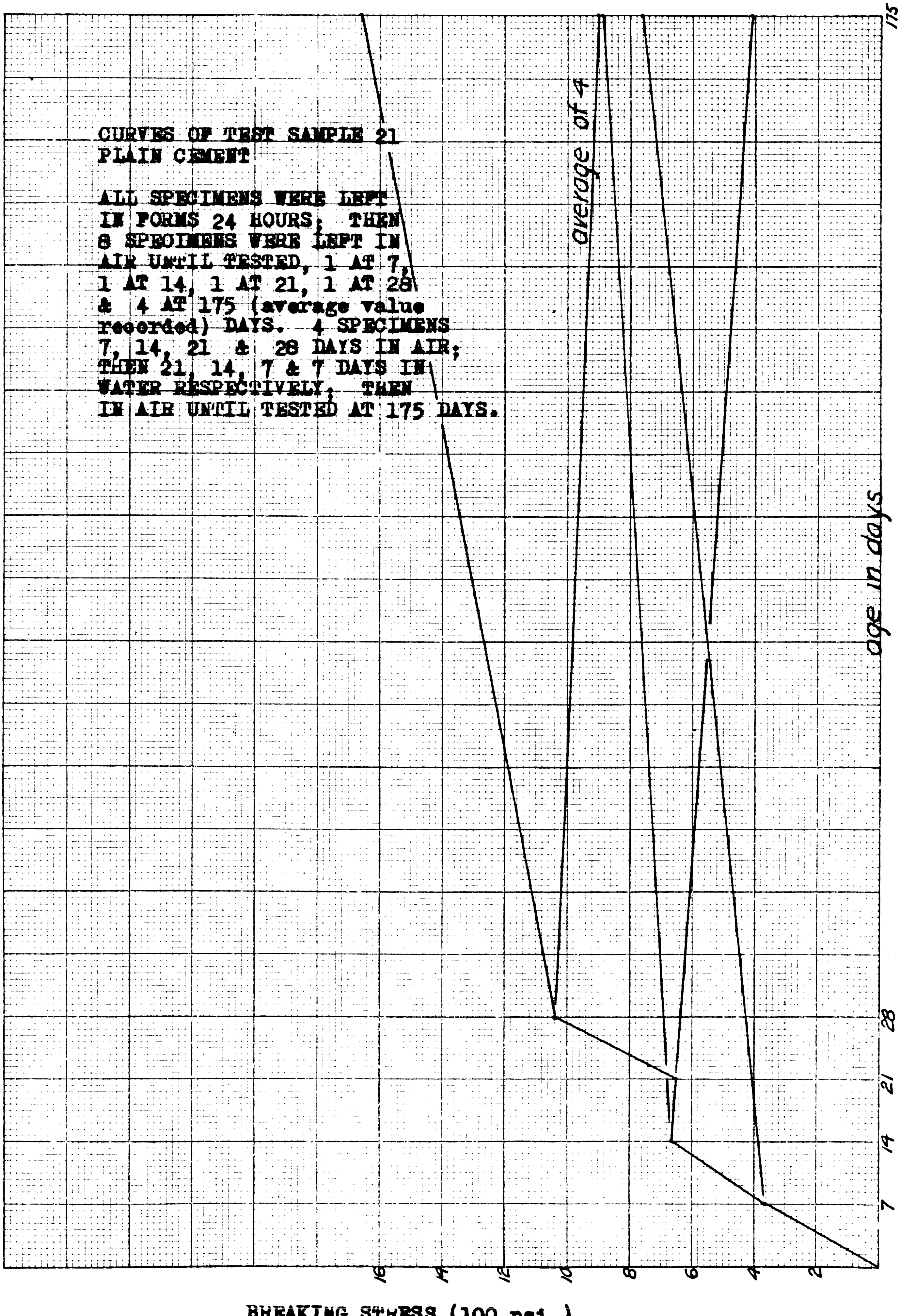


CURVES OF TEST SAMPLE 19
UREA-FORMALDAHYDE-PHENOL-CEMENT
EL. SET.
ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21 & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



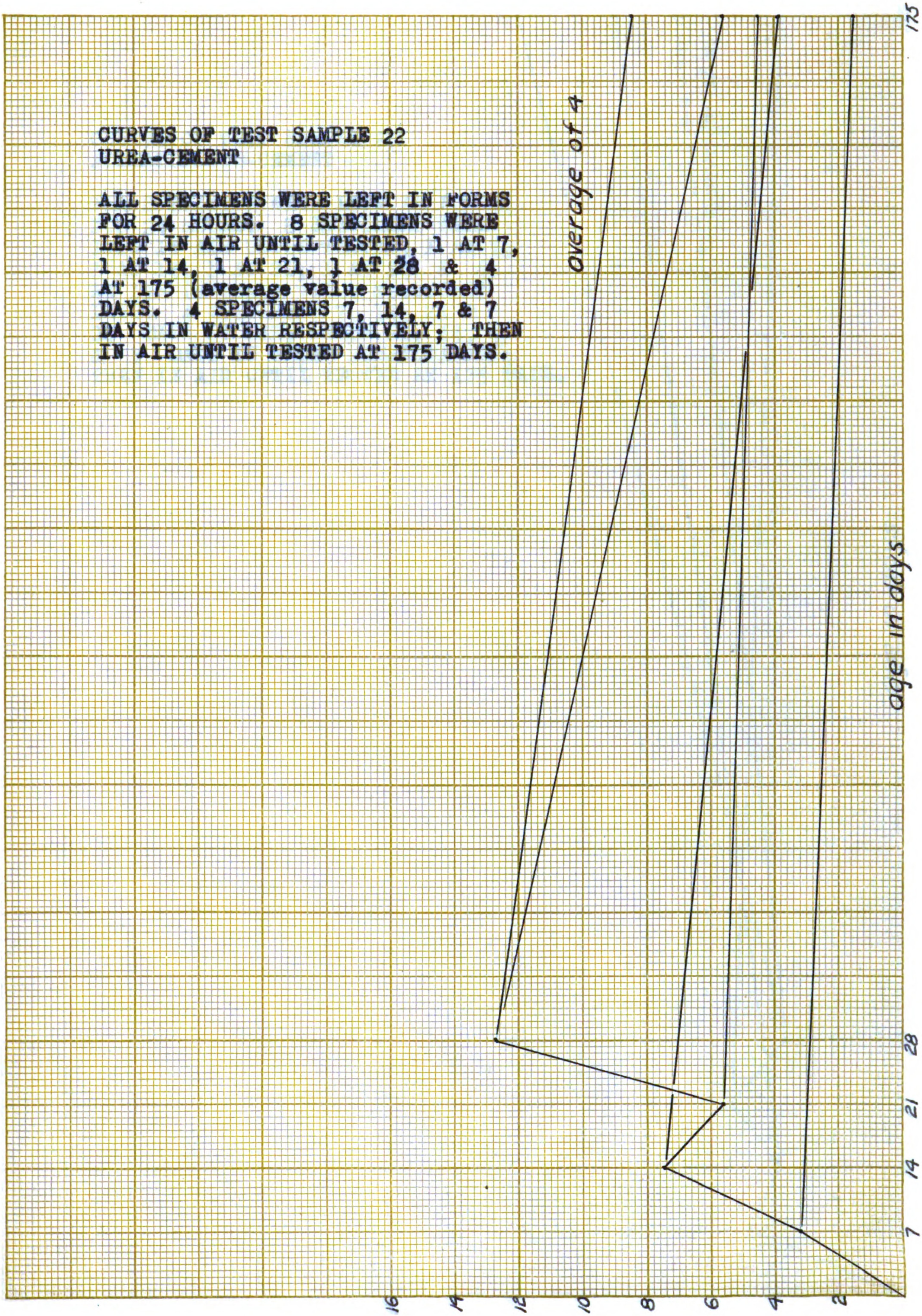
CURVES OF TEST SAMPLE 20
PLAIN CEMENT - EL. SET.

ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR, THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY, THEN IN AIR UNTIL TESTED AT 175 DAYS.



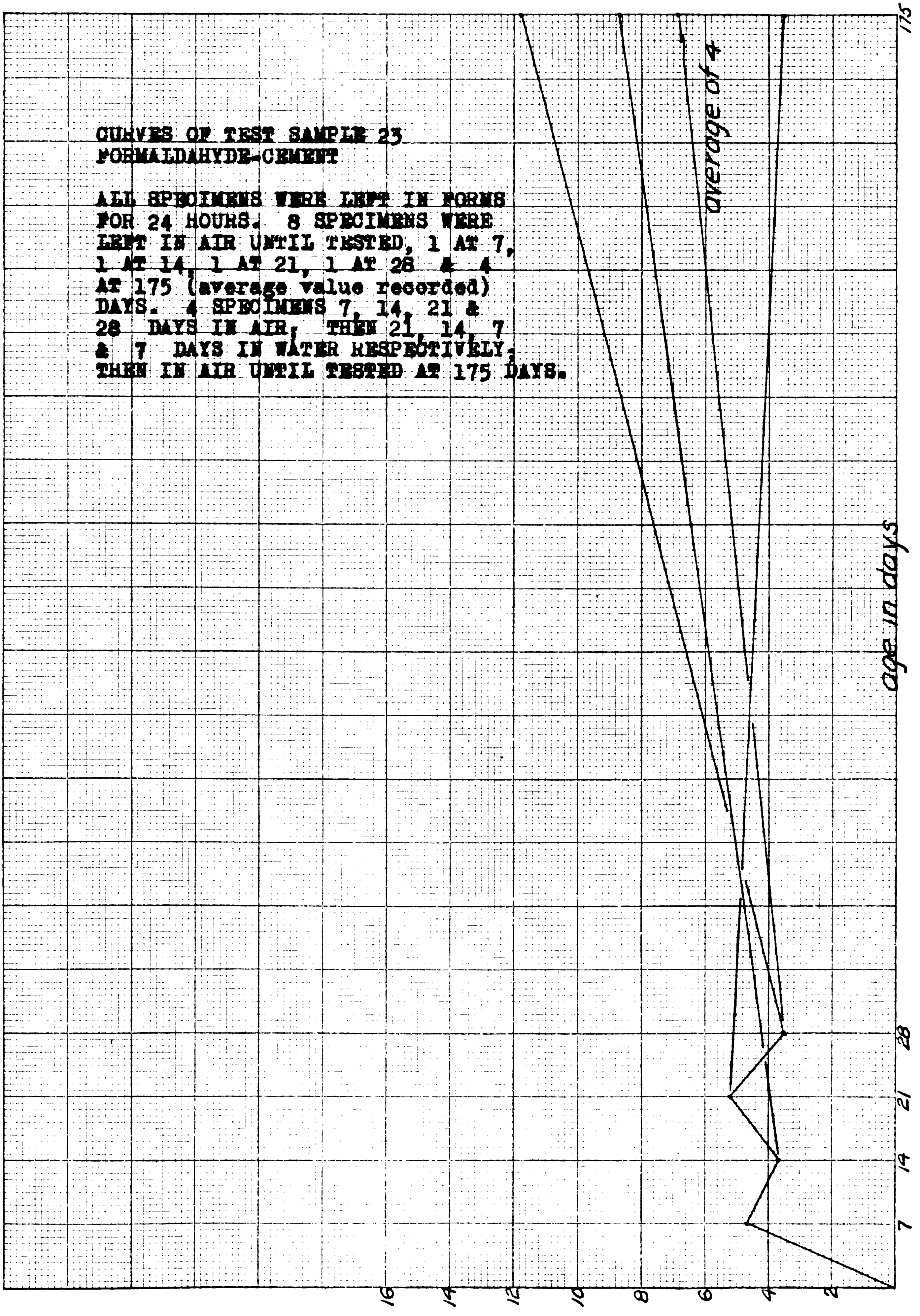
CURVES OF TEST SAMPLE 21
PLAIN CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR; THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY, THEN IN AIR UNTIL TESTED AT 175 DAYS.



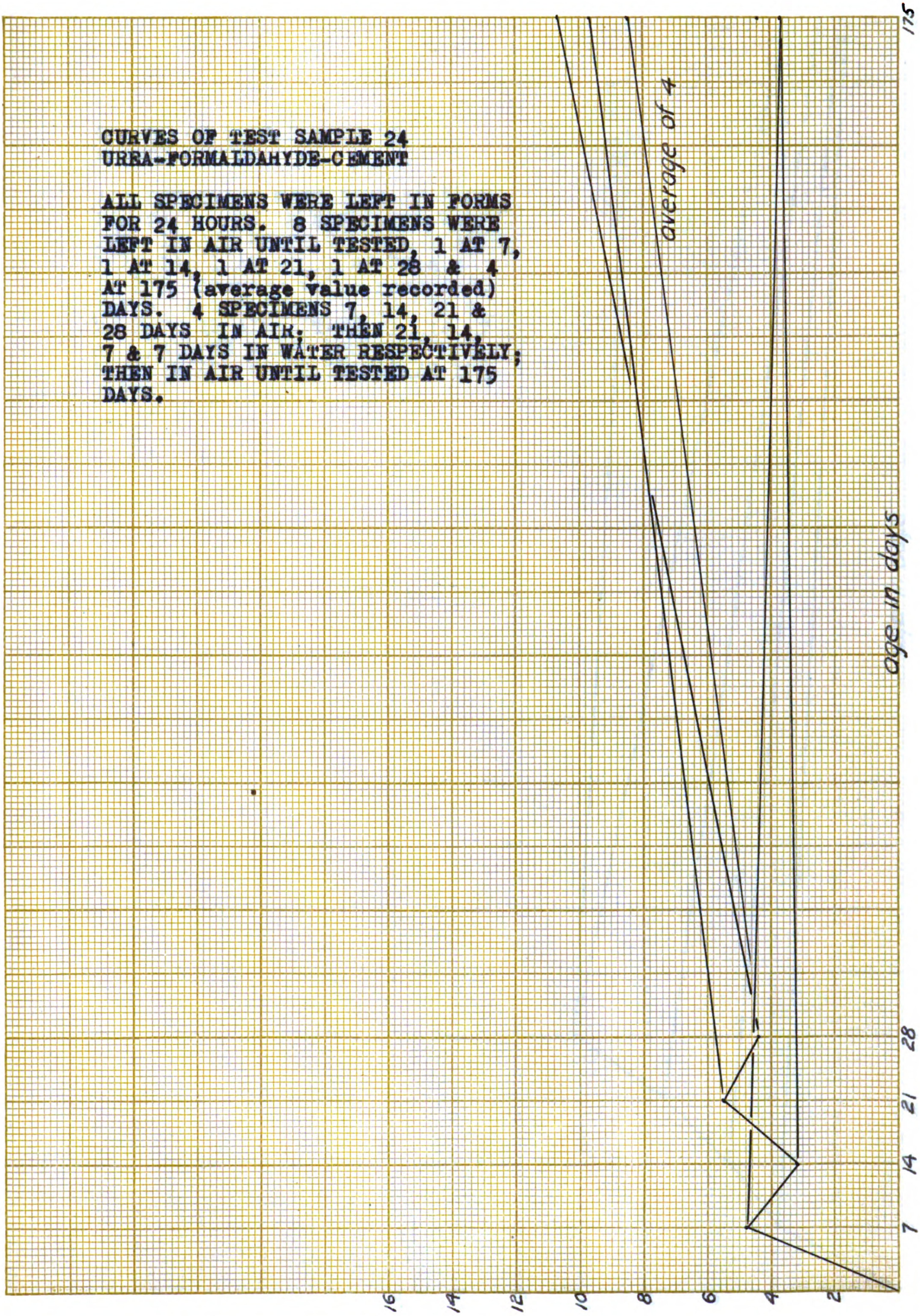
CURVES OF TEST SAMPLE 22
UREA-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 7 & 7 DAYS IN WATER RESPECTIVELY; THEN IN AIR UNTIL TESTED AT 175 DAYS.



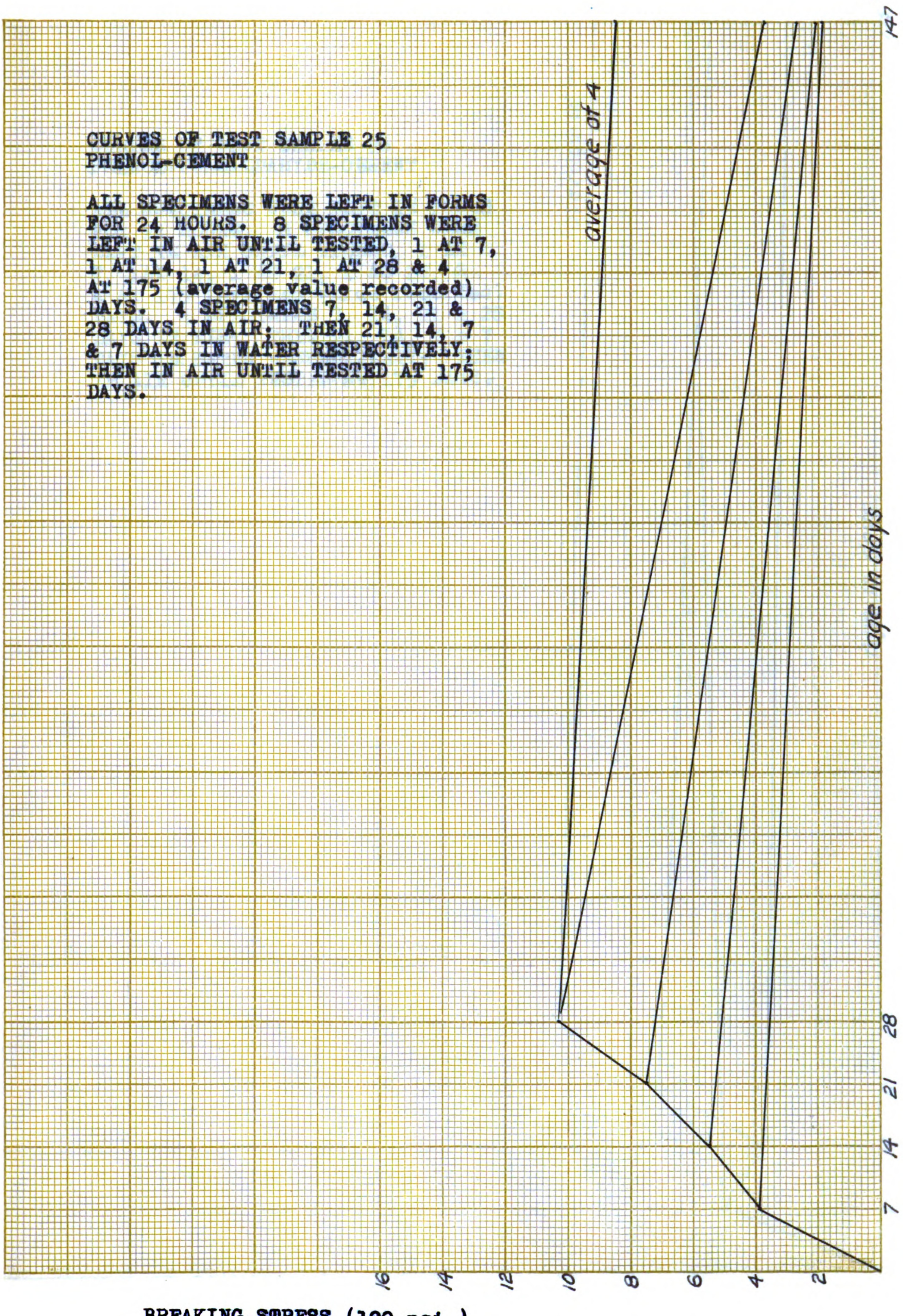
CURVES OF TEST SAMPLE 23
FORMALDAHYDE-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR, THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY, THEN IN AIR UNTIL TESTED AT 175 DAYS.



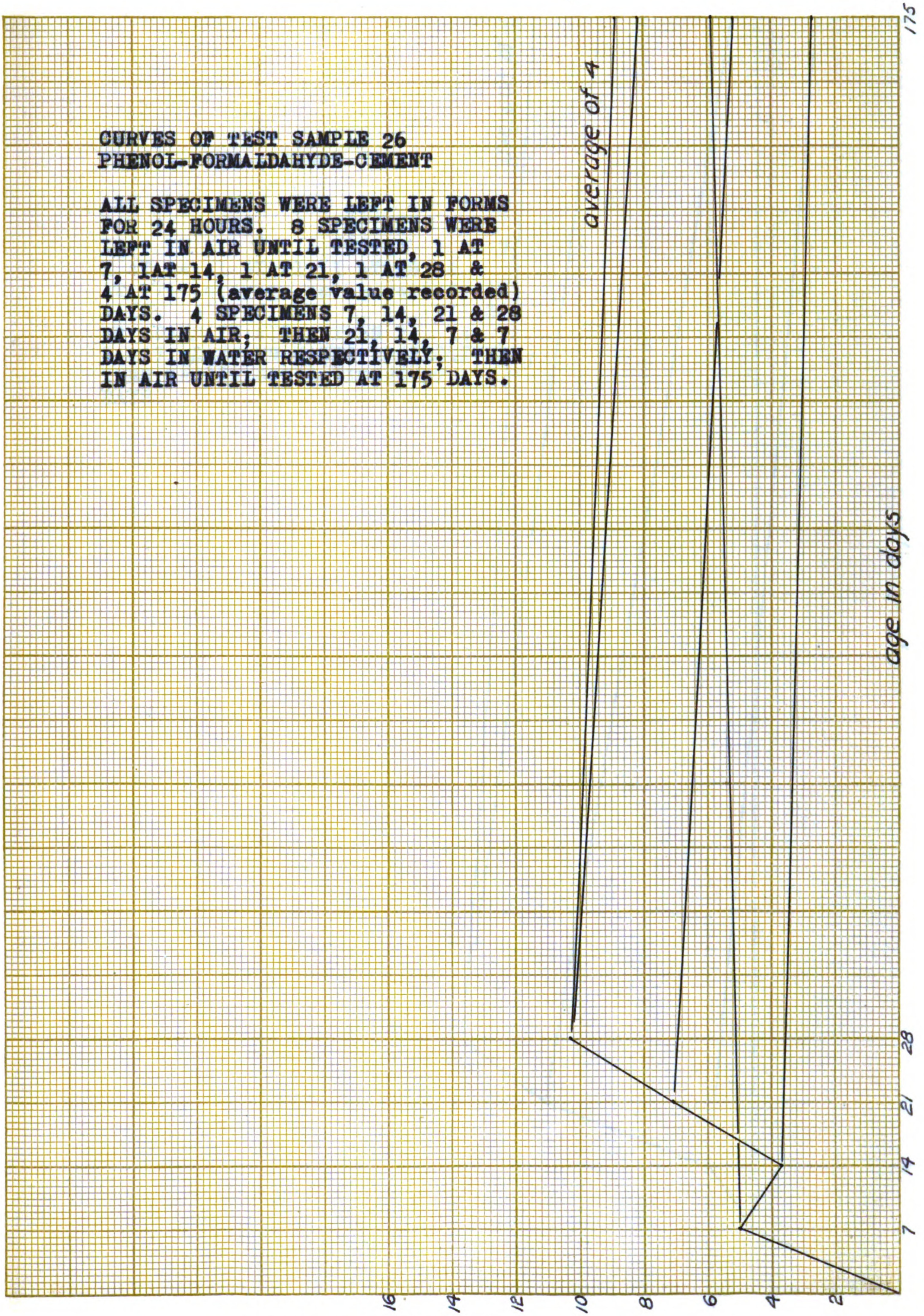
CURVES OF TEST SAMPLE 24
URRA-FORMALDAHYDE-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR. THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY; THEN IN AIR UNTIL TESTED AT 175 DAYS.



CURVES OF TEST SAMPLE 25
PHENOL-CEMENT

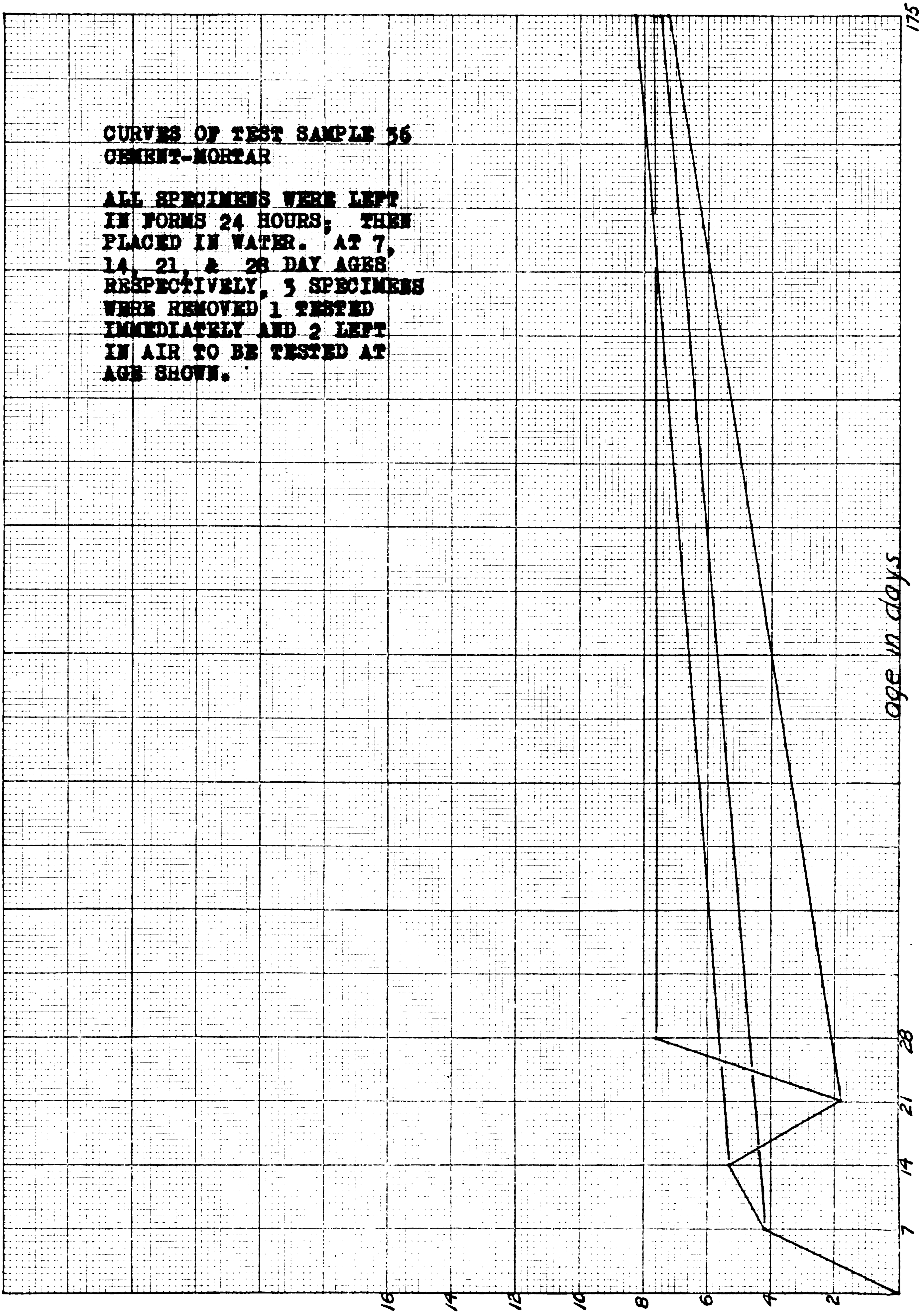
ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR, THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY, THEN IN AIR UNTIL TESTED AT 175 DAYS.



CURVES OF TEST SAMPLE 26
PHENOL-FORMALDAHYDE-CEMENT

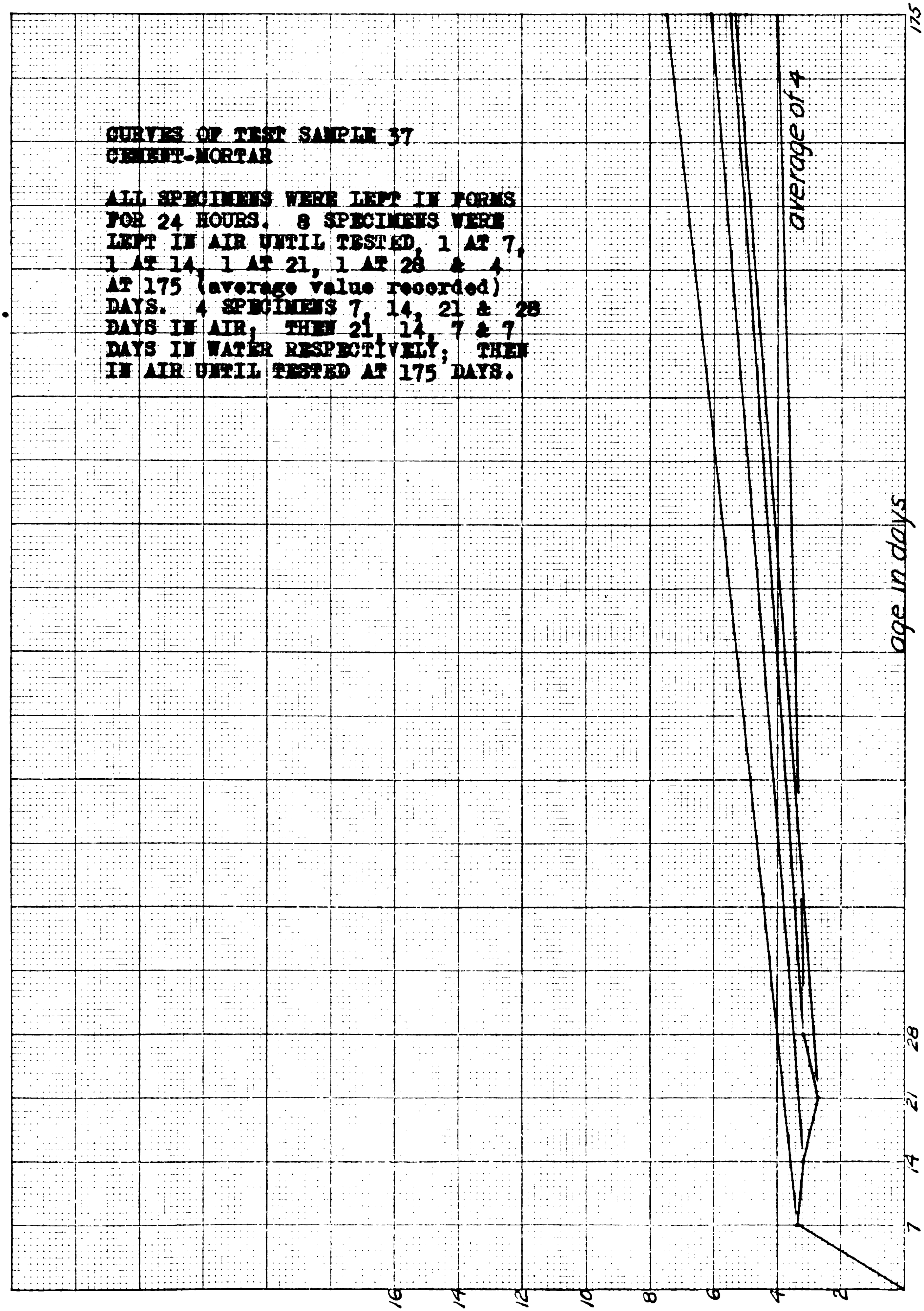
ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR; THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY; THEN IN AIR UNTIL TESTED AT 175 DAYS.

BREAKING STRESS (100 [illegible])



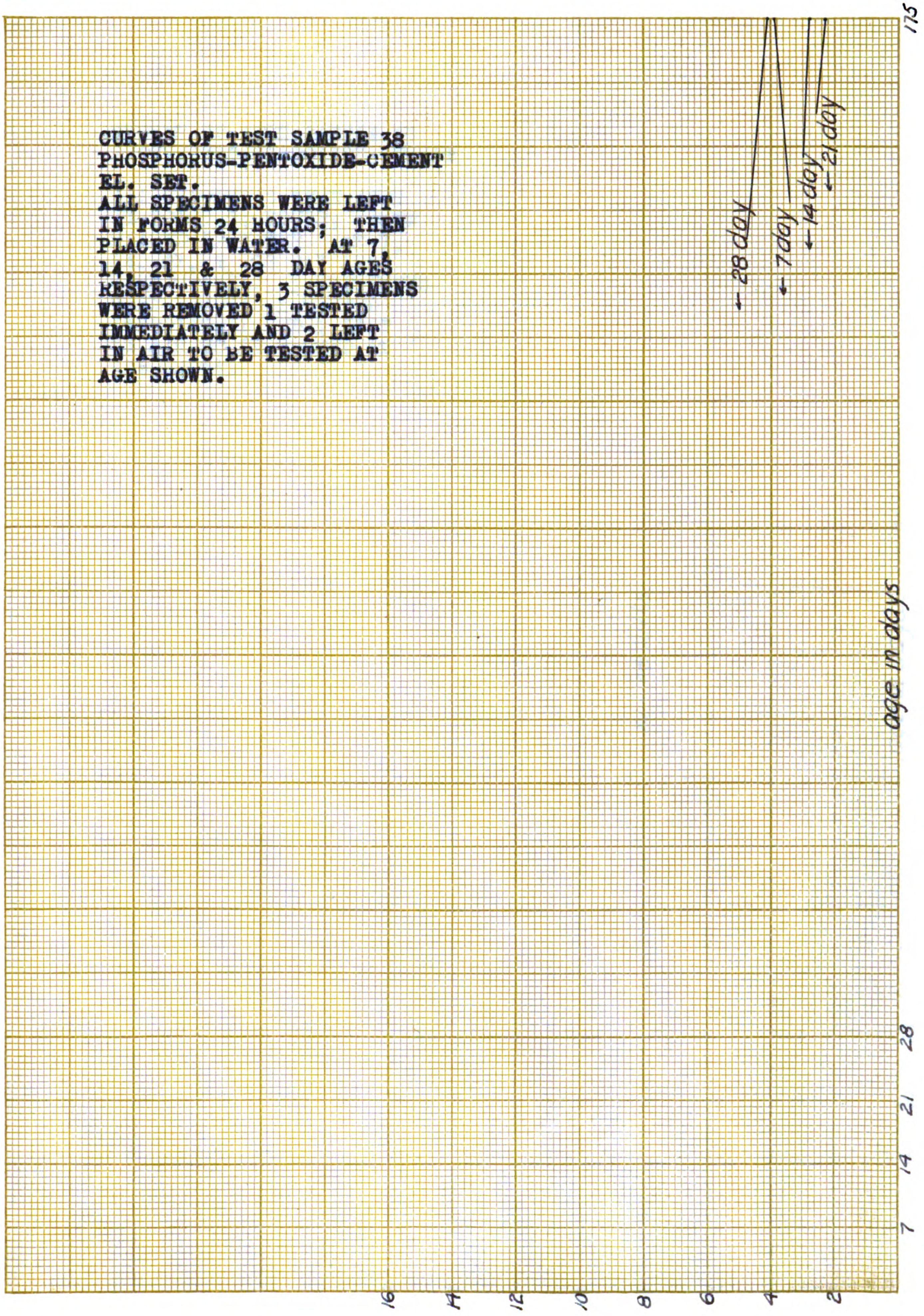
CURVES OF TEST SAMPLE 36
CEMENT-MORTAR

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.

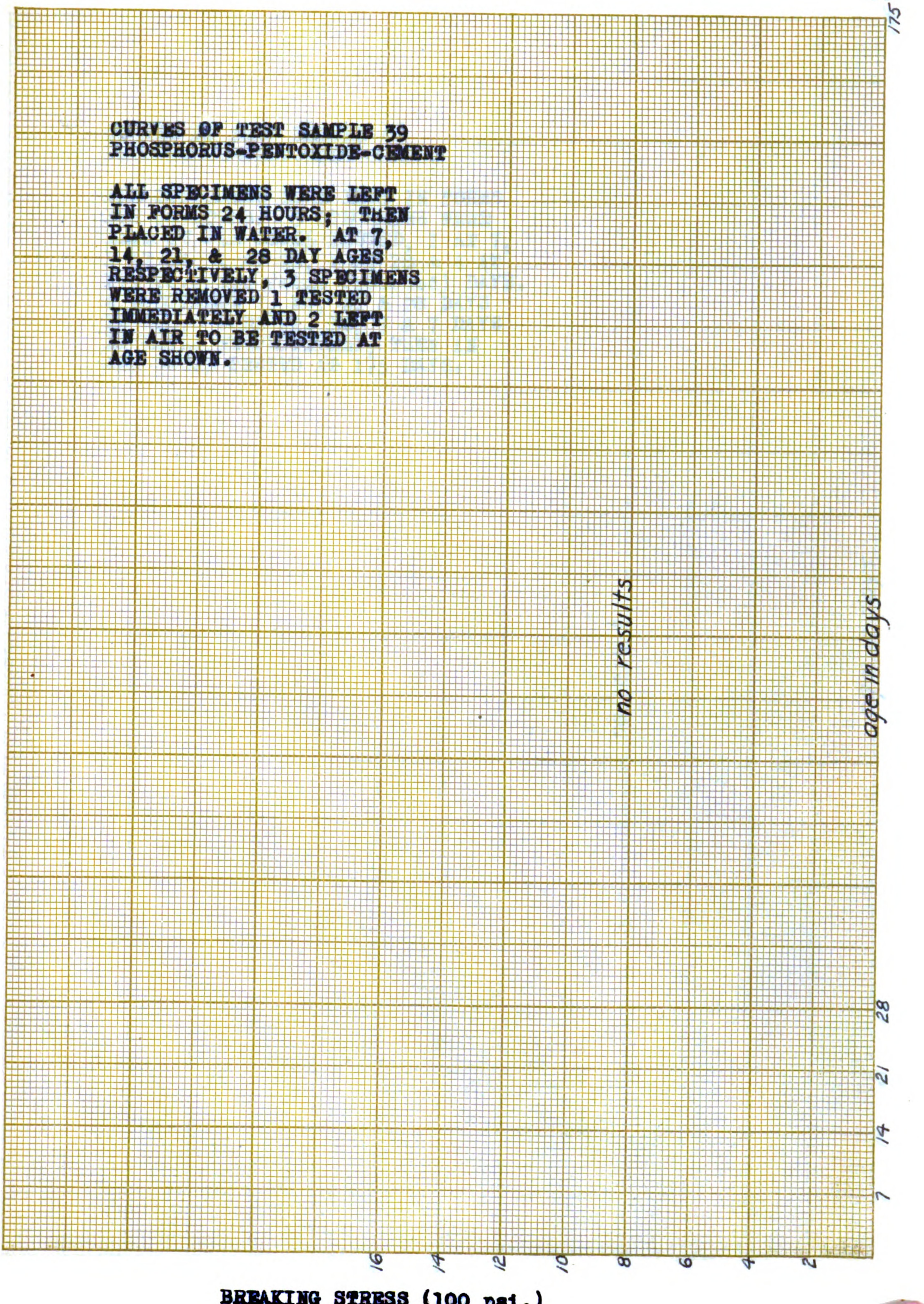


CURVES OF TEST SAMPLE 37
CEMENT-MORTAR

ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR, THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY; THEN IN AIR UNTIL TESTED AT 175 DAYS.



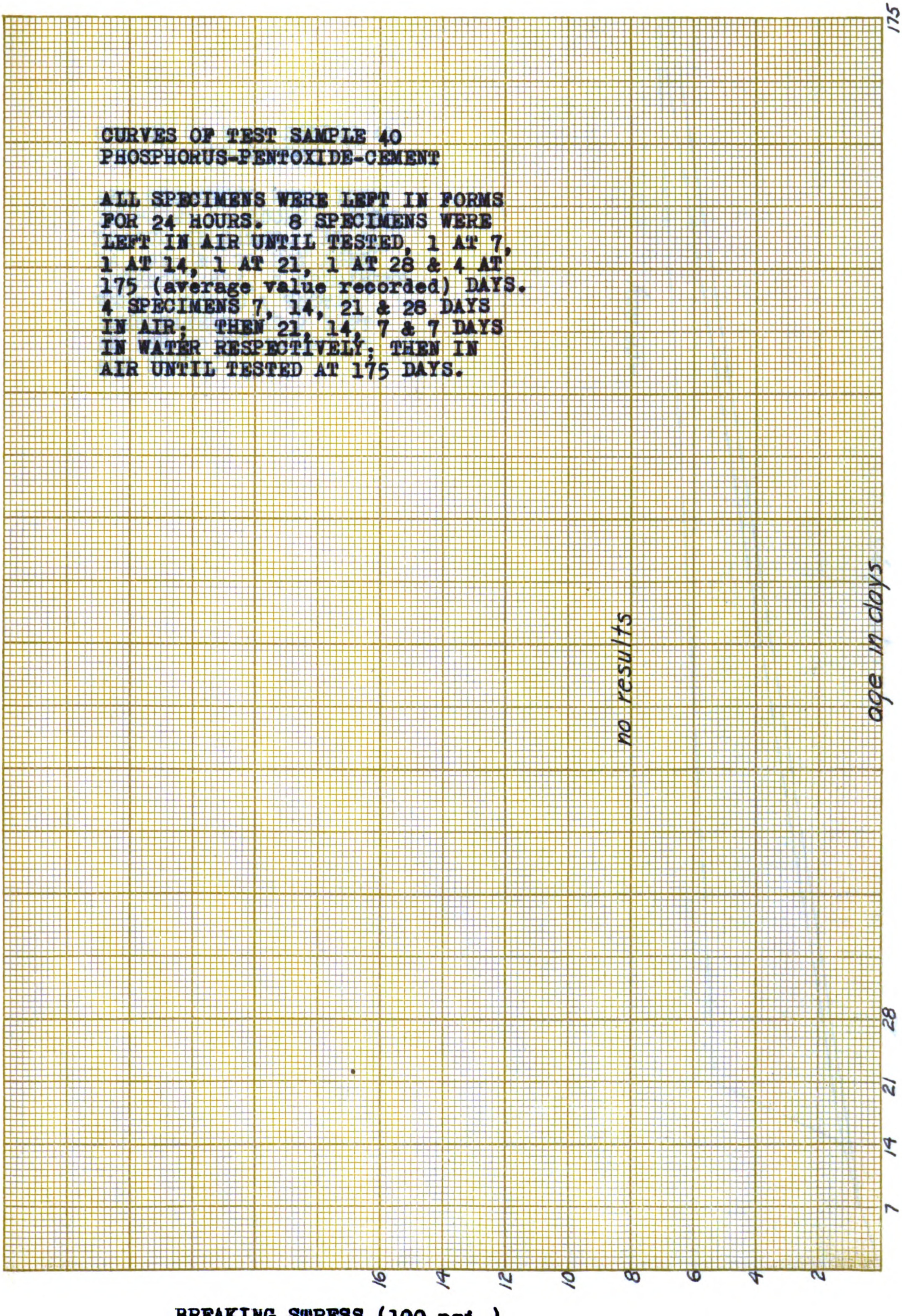
CURVES OF TEST SAMPLE 38
PHOSPHORUS-PENTOXIDE-CEMENT
EL. SET.
ALL SPECIMENS WERE LEFT
IN FORMS 24 HOURS; THEN
PLACED IN WATER. AT 7,
14, 21 & 28 DAY AGES
RESPECTIVELY, 3 SPECIMENS
WERE REMOVED 1 TESTED
IMMEDIATELY AND 2 LEFT
IN AIR TO BE TESTED AT
AGE SHOWN.



CURVES OF TEST SAMPLE 39
PHOSPHORUS-PENTOXIDE-CEMENT

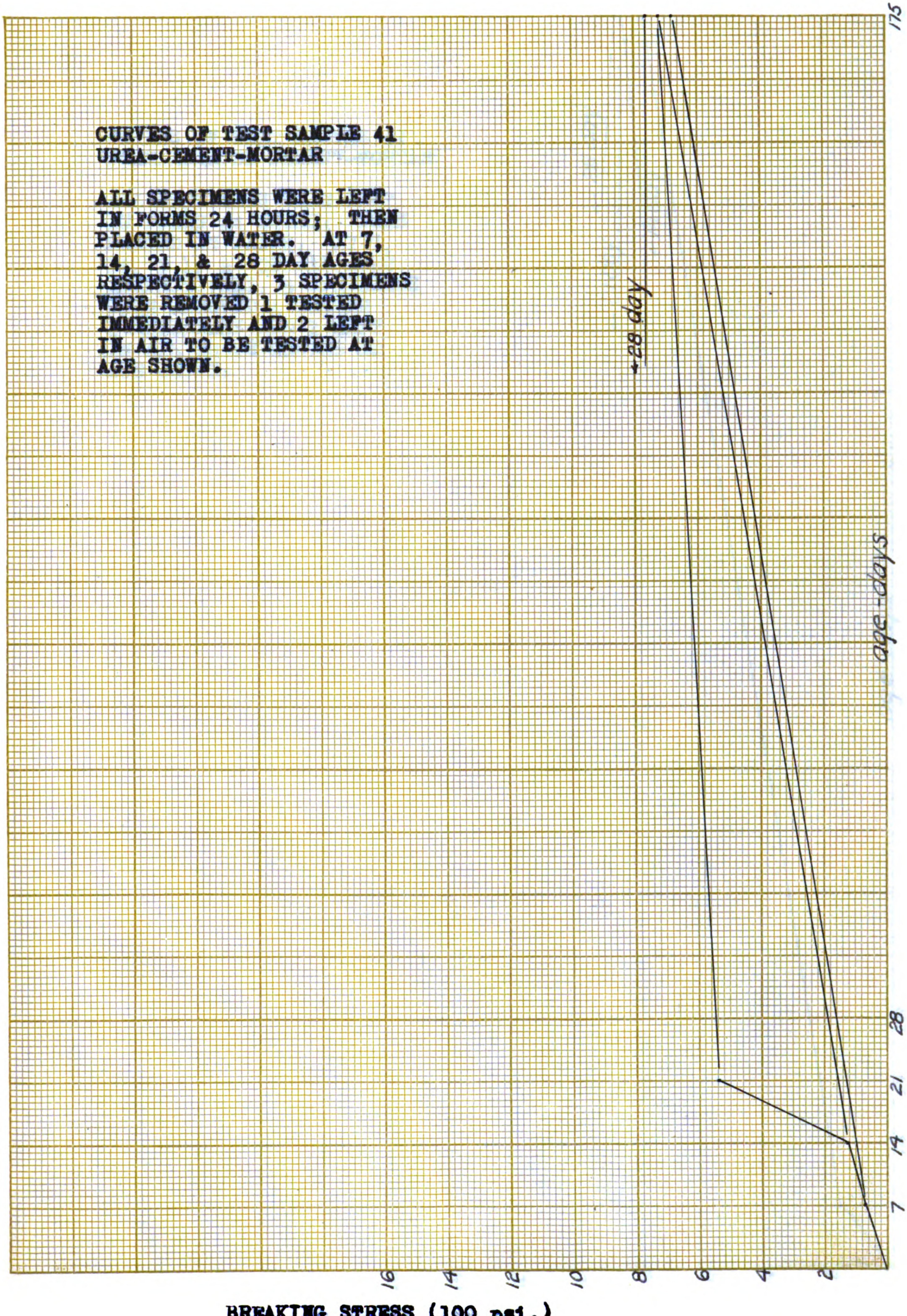
ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.

no results



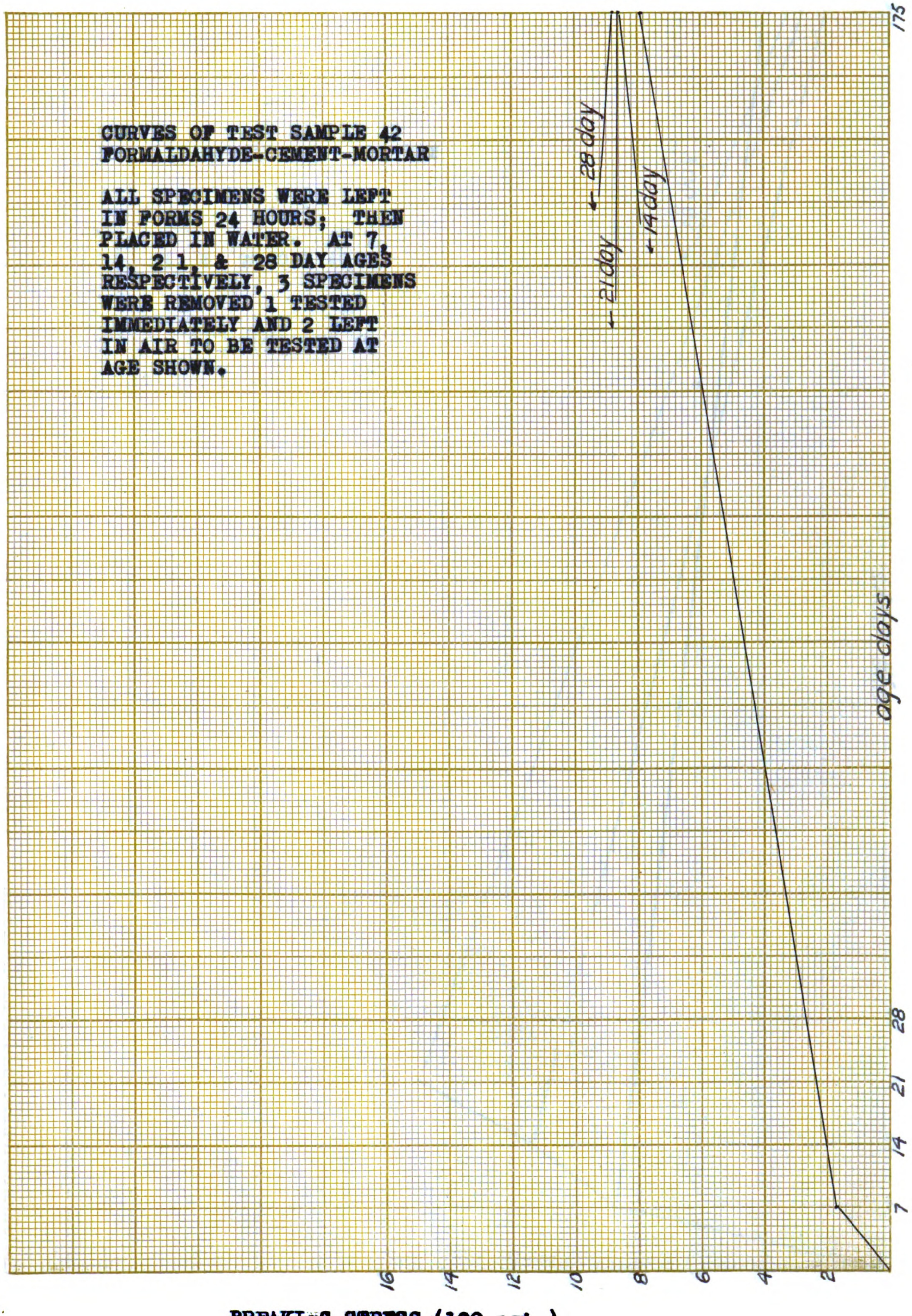
CURVES OF TEST SAMPLE 40
PHOSPHORUS-PENTOXIDE-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR; THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY; THEN IN AIR UNTIL TESTED AT 175 DAYS.



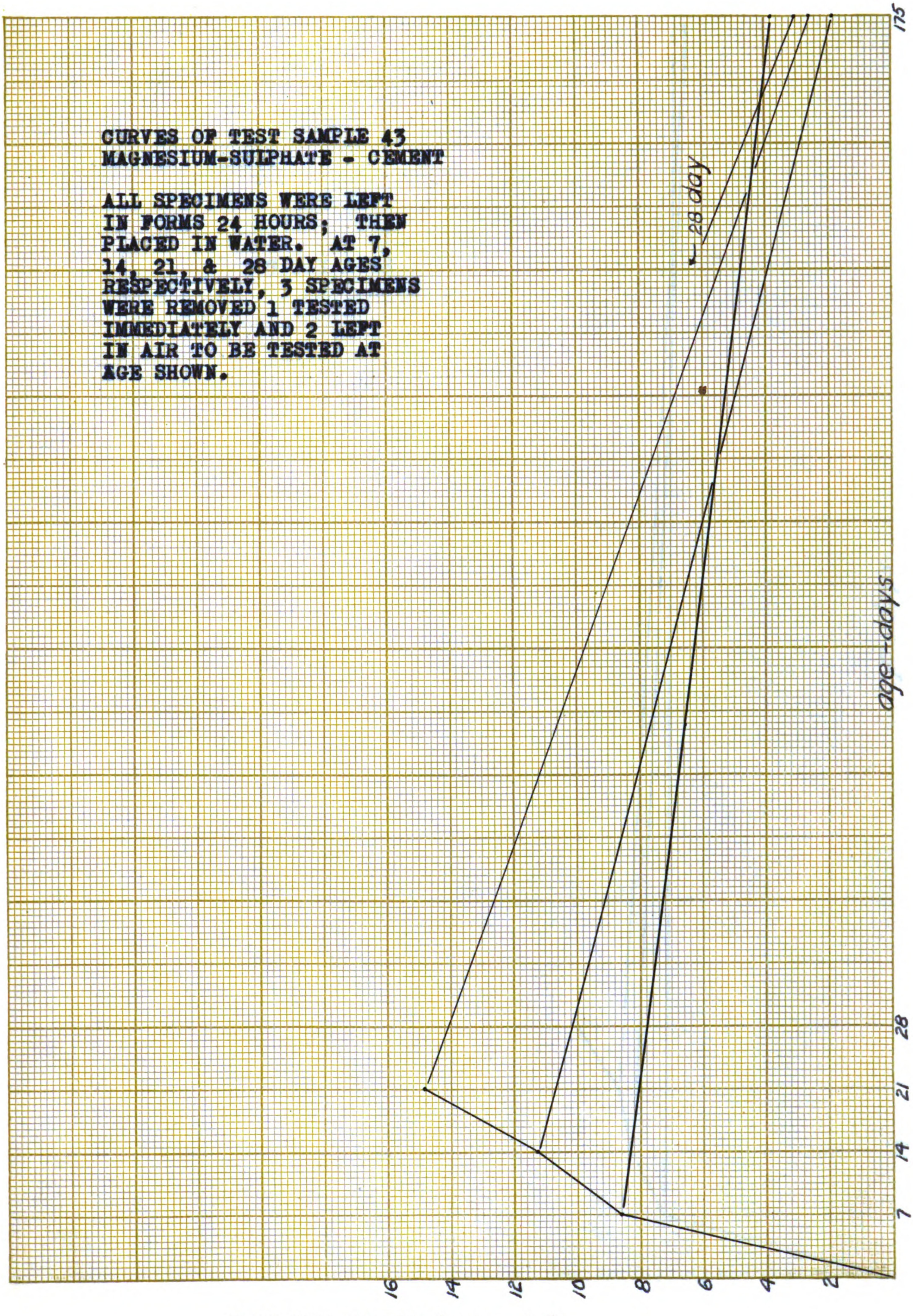
CURVES OF TEST SAMPLE 41
URBA-CEMENT-MORTAR

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



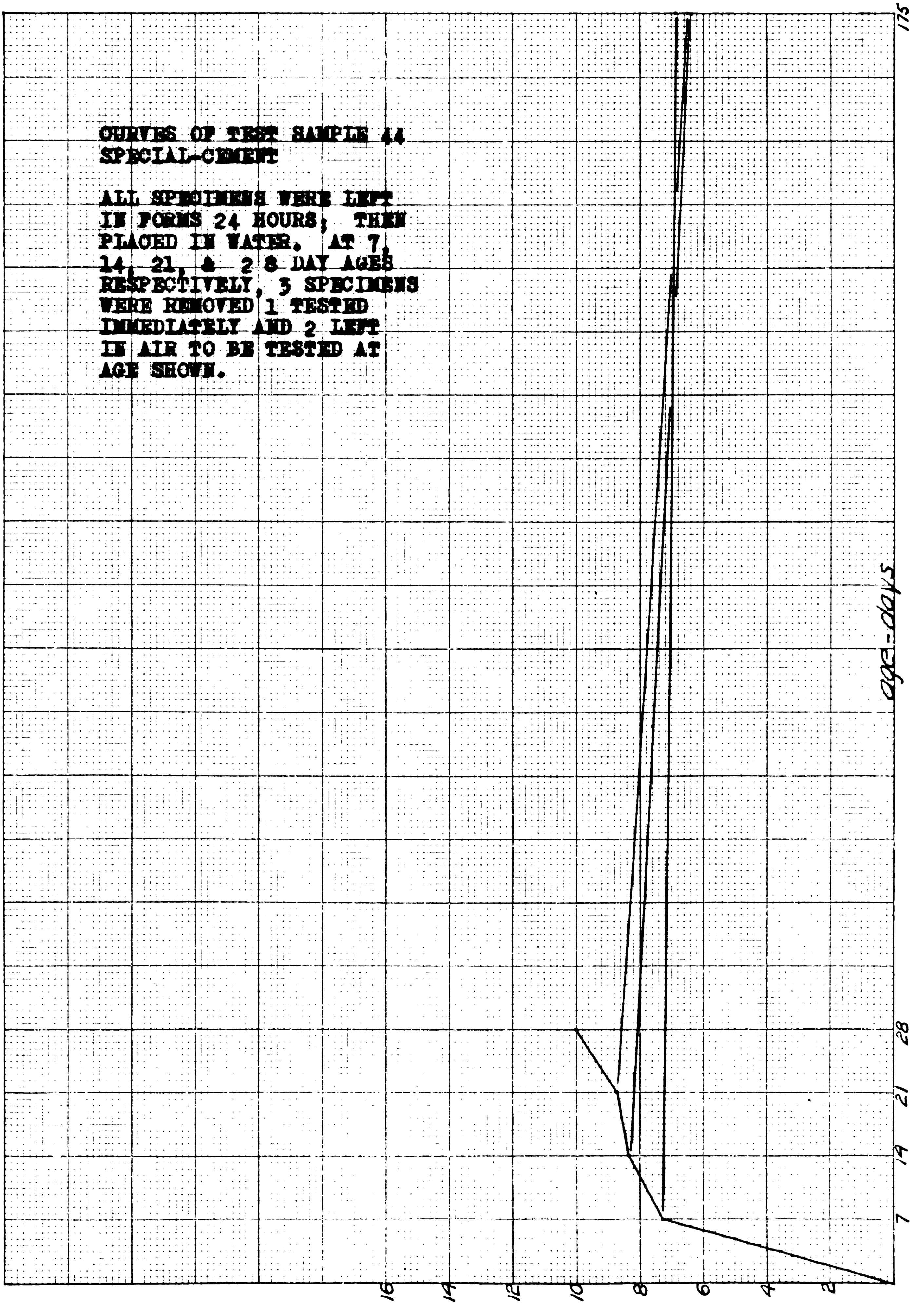
CURVES OF TEST SAMPLE 42
FORMALDAHYDE-CEMENT-MORTAR

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 2 1, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



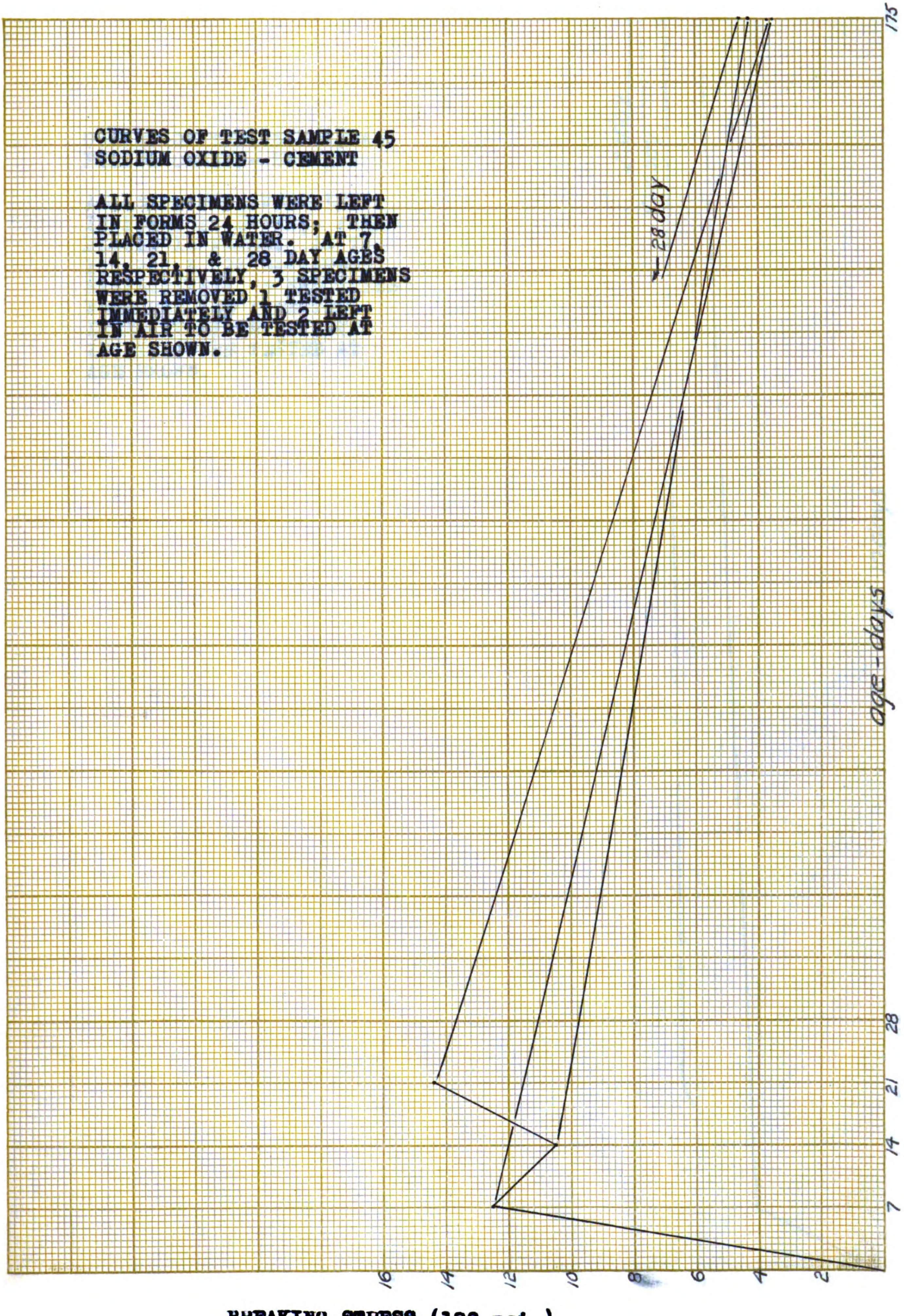
CURVES OF TEST SAMPLE 43
MAGNESIUM-SULPHATE - CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



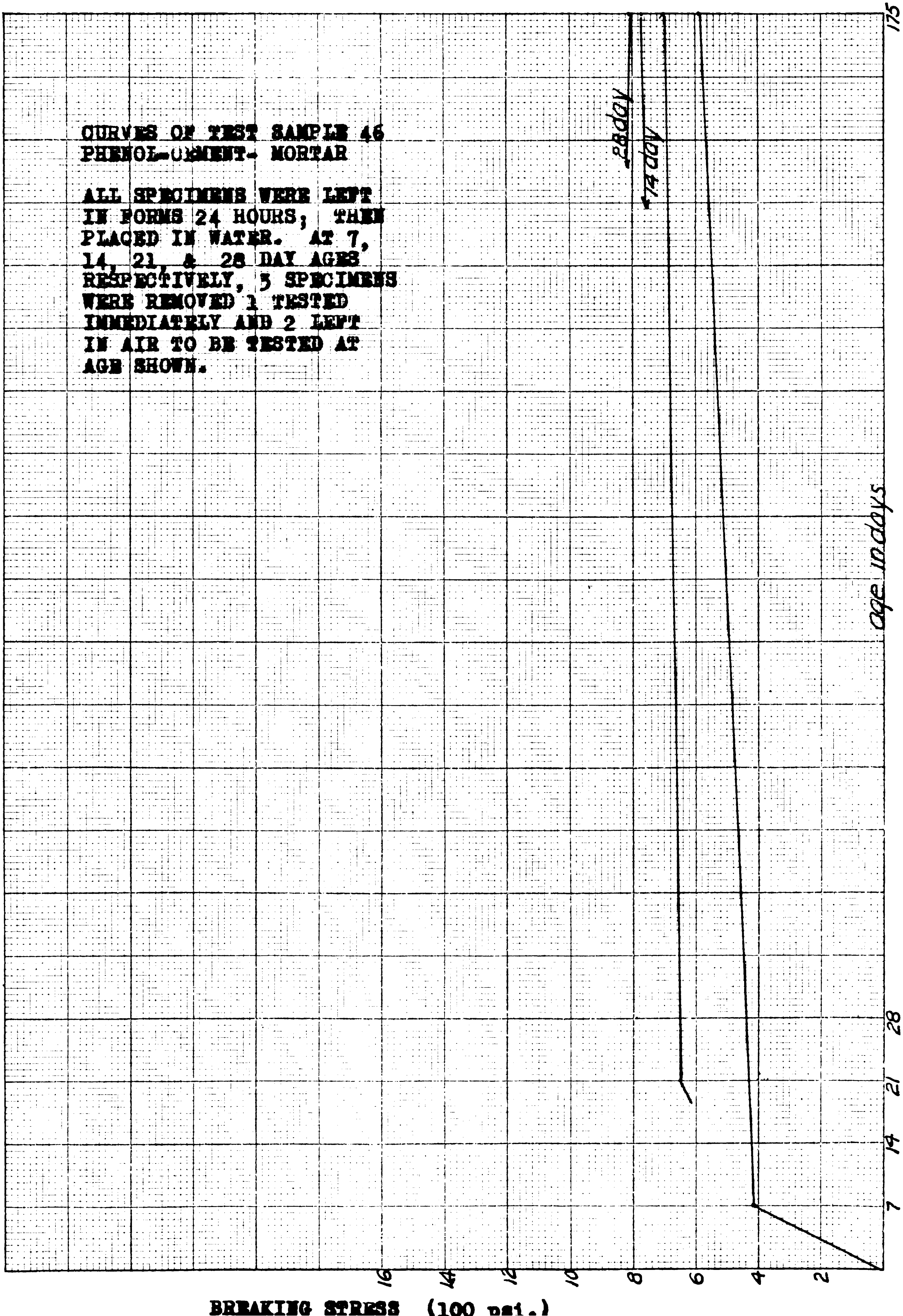
CURVES OF TEST SAMPLE 44
SPECIAL-CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



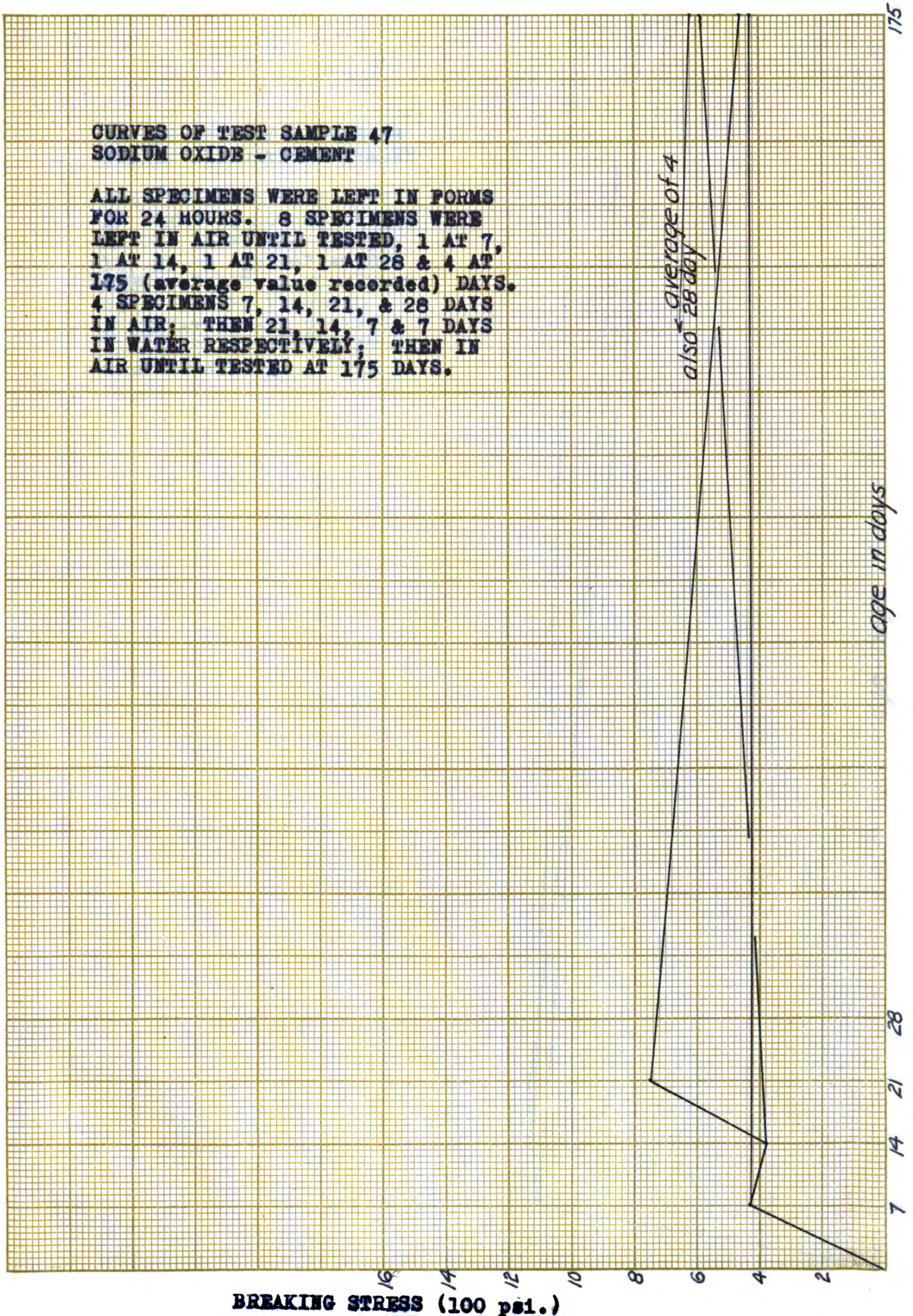
CURVES OF TEST SAMPLE 45
SODIUM OXIDE - CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



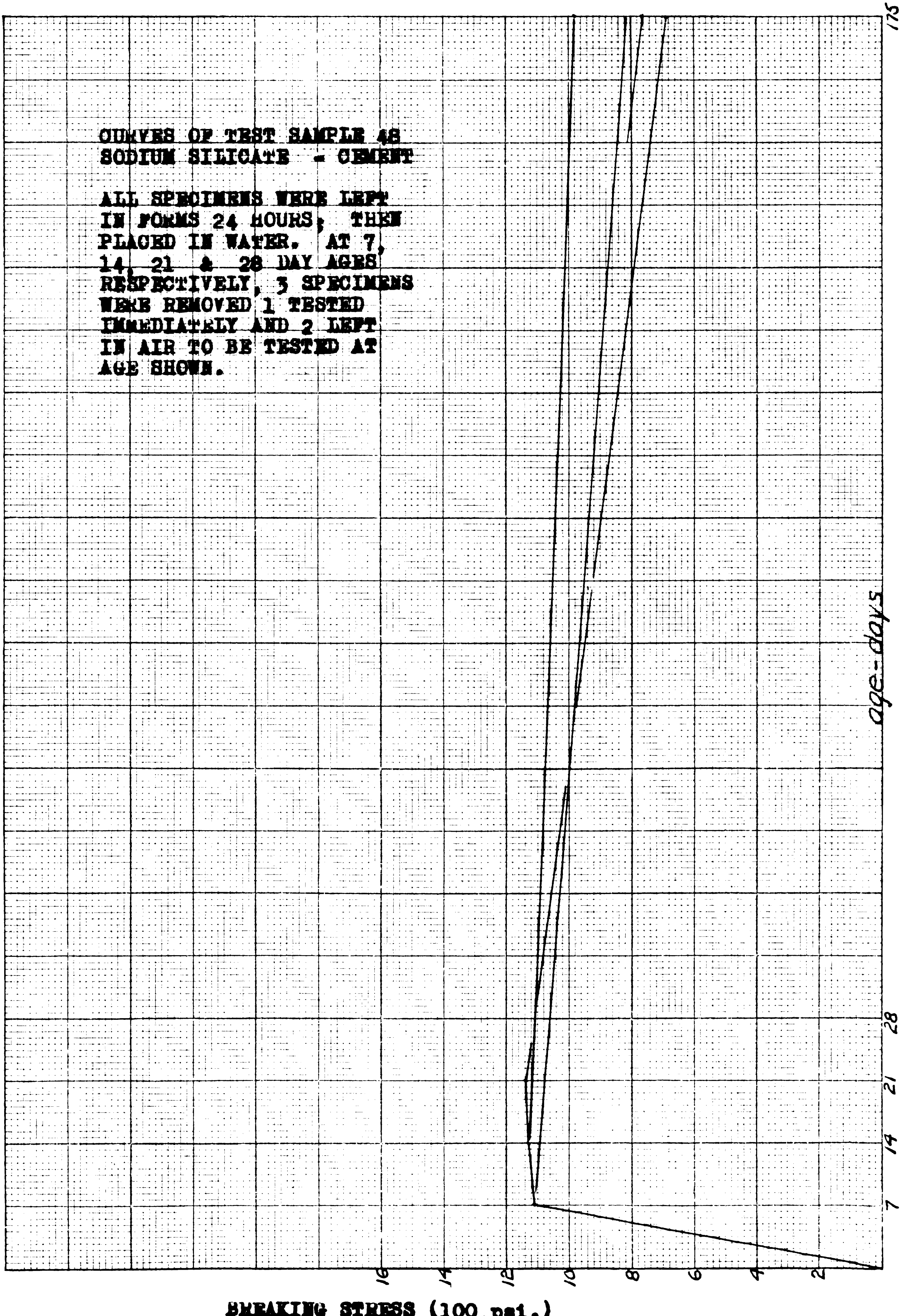
CURVES OF TEST SAMPLE 46
PHENOL-CEMENT- MORTAR

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21, & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



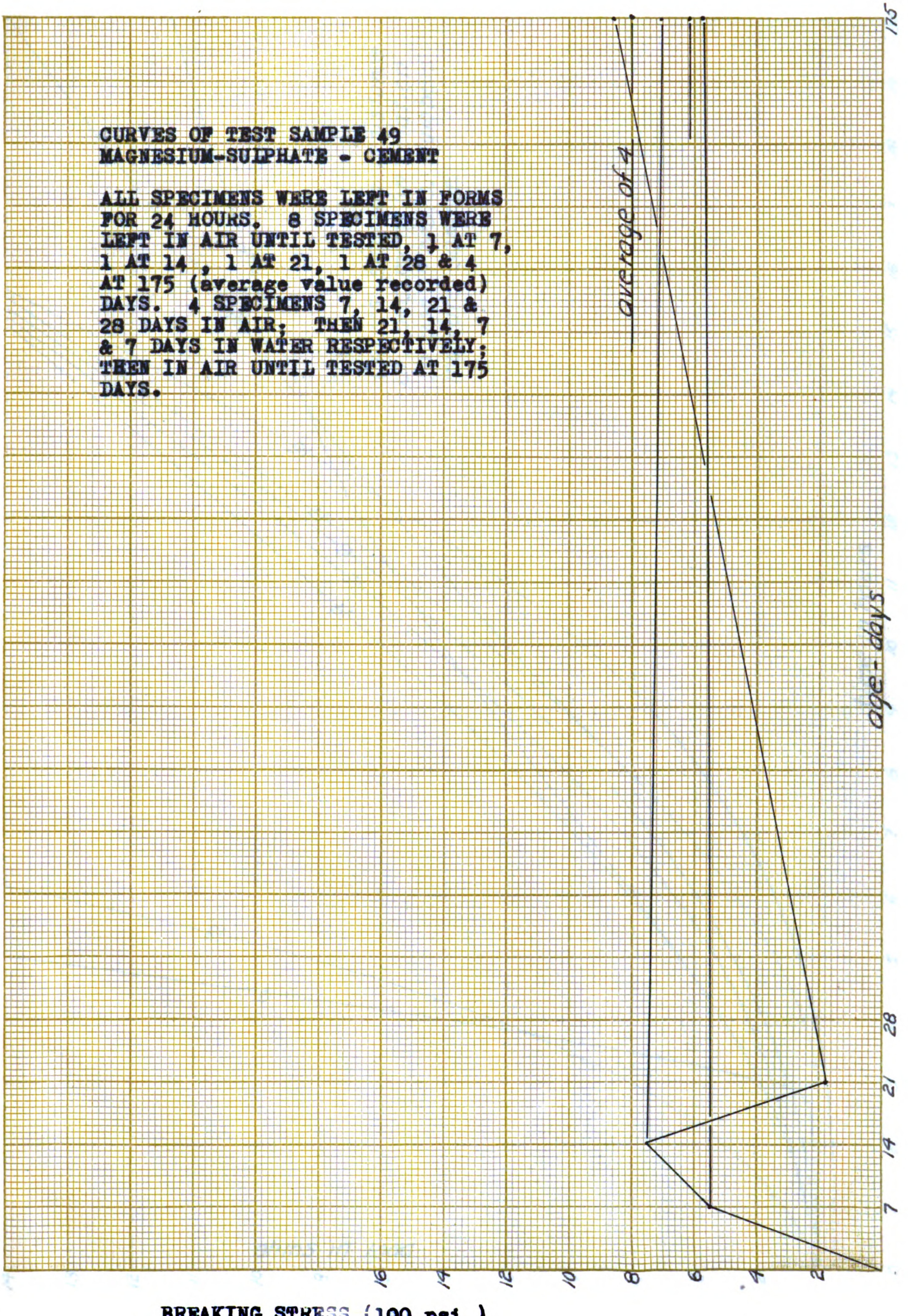
CURVES OF TEST SAMPLE 47
SODIUM OXIDE - CEMENT

ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14, 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21, & 28 DAYS IN AIR. THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY, THEN IN AIR UNTIL TESTED AT 175 DAYS.



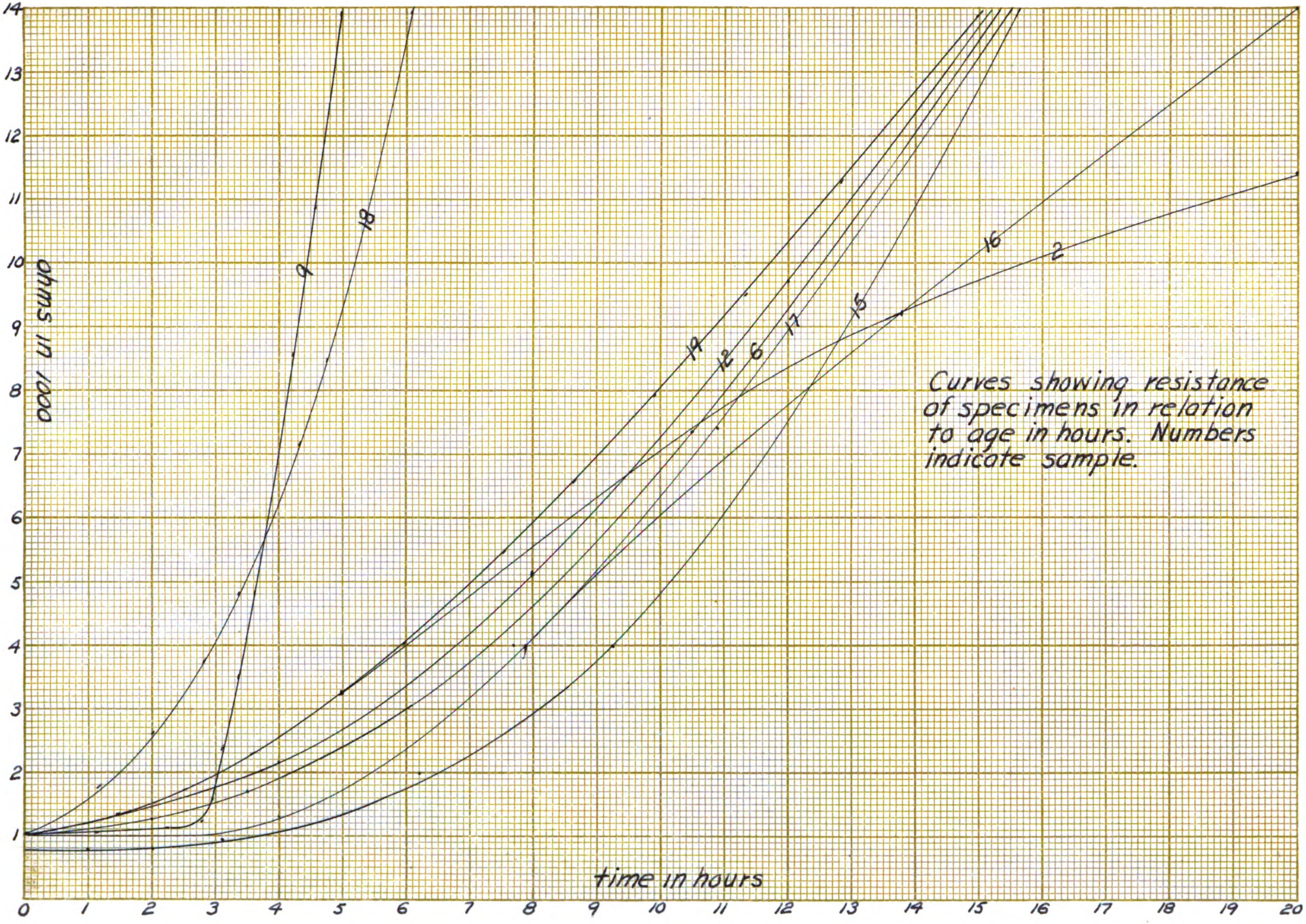
CURVES OF TEST SAMPLE 48
SODIUM SILICATE - CEMENT

ALL SPECIMENS WERE LEFT IN FORMS 24 HOURS; THEN PLACED IN WATER. AT 7, 14, 21 & 28 DAY AGES RESPECTIVELY, 3 SPECIMENS WERE REMOVED 1 TESTED IMMEDIATELY AND 2 LEFT IN AIR TO BE TESTED AT AGE SHOWN.



CURVES OF TEST SAMPLE 49
MAGNESIUM-SULPHATE - CEMENT

ALL SPECIMENS WERE LEFT IN FORMS FOR 24 HOURS. 8 SPECIMENS WERE LEFT IN AIR UNTIL TESTED, 1 AT 7, 1 AT 14 , 1 AT 21, 1 AT 28 & 4 AT 175 (average value recorded) DAYS. 4 SPECIMENS 7, 14, 21 & 28 DAYS IN AIR; THEN 21, 14, 7 & 7 DAYS IN WATER RESPECTIVELY, THEN IN AIR UNTIL TESTED AT 175 DAYS.



Curves showing resistance of specimens in relation to age in hours. Numbers indicate sample.