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AN INVESTIGATION OF BLENDED CEMENTS.

5969

BY

BYRON LEE ASHDOWN.

A

THESIS

submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the
Degree of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

Rolla, Mo.

1916.

Approved by - - - - -

Assistant Professor of Civil Engineering.

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To Mr. H. R. Risher, who conducted and aided the writer in a few of the tests, he is also very thankful.

He also wishes to thank Mr. R. P. Rinker, of the Geological Survey of Missouri, who has assisted him by running the chemical analysis of the blend and portland cements used in the working of this thesis, and finally he wishes to acknowledge the receipt of the blend from the Ottawa Sand Company, and of the Atlas, Lehigh, and Red Ring cements for their respective manufacturers, and to thank each of these manufacturers for their liberality.

INTRODUCTION:

It is generally accepted to be a fact that the coarser particles of a cement are practically inert, and that it is only the finest particles that possess the cementing qualities. Exactly what percentage of the whole is active, or possesses the cementing properties, is not known. Since but few experiments pertaining to such have been performed there is consequently little data to be found. In the absence of this data one could, with a fair degree of accuracy, assume that all particles of a portland cement retained on a No. 200 sieve are practically inert and have little or no cementing qualities. It is almost safe to say that a considerable percentage of the particles passing the No. 200 sieve are also inert and devoid of cementing properties. This percentage could be greatly reduced, perhaps, by grinding the clinker for a longer time, but whether or not this is practicable is a question.

It seems most probable that if cement were ground finer than is required by the accepted specifications marked changes in its physical properties would result. The resultant cement when used in mortars and concrete would also change

their physical properties. There would be, perhaps, an acceleration in the time of set, a modification in tensile and compressive strength, and, possibly, a less constancy of volume. Besides this there would be a considerable increase in the cost of production. An increase in strength is highly desirable; a rapid setting cement, however, is unsuitable for some classes of construction; and a cement which lacks constancy of volume disintegrates. If, then, some method could be devised whereby an increase of strength could be obtained or the same strength obtained with a smaller quantity of cement, and the disintegrating and rapid setting tendencies eliminated some beneficial results might be achieved. It is the purpose of this thesis to try out a method which has been suggested to the writer to accomplish these results by means of blended cements.

BLENDÉD CEMENT:

Blended cement is the resultant cement produced by intimately incorporating in a standard portland cement finely divided and practically inert material such as clay or powdered rock; but no especial

attention has been given to the percentage of fineness of the portland cement - - only that it pass the standard specifications. Blended cements have been used successfully and economically, and are continuing to be favored in the construction of numerous heavy structures. The United States Reclamation Service and the Los Angeles Aqueduct Commission have made use of blended cements in the heavy structures built by them.

PURPOSE OF THESIS:

This reference to the use of blended cements has been given to call attention to the fact that this product has been used for some years and experience has shown that the standard portland cement can be diluted, so to speak, without harmful results. It is, then, the purpose of this investigation to determine the effect of blending a portland cement, which passes a No. 200 sieve, with an inert material, which is itself very finely powdered, in an attempt to accomplish the results mentioned above.

NOMENCLATURE:

Throughout this report the following nomenclature will be used:

Portland cement as received from the cement plants will be referred to as "portland cement."

Those particles of the portland cement passing a No. 200 sieve will be termed "active particles" and those retained on a No. 200 sieve will be termed "inert particles."

Powdered material to be mixed with the active particles will be called the "blend."

The product produced by intimately mixing the blend and active particles will be designated as "blended cement."

PORTLAND CEMENTS USED:

The following brands of portland cement were used:

- (A) Atlas portland.
- (B) Lehigh portland.
- (C) Red Ring portland.

These brands will be referred to throughout the report by their respective letters.

THE BLEND:

The blend used was prepared by the Ottawa Sand Company by grinding natural sand until all passed a No. 65 sieve.

THE BLENDED CEMENTS:

The blended cements were prepared by intimately mixing the blend and the active particles in varying percentages which will be described in detail later.

PREPARATION OF THE BLENDED CEMENTS & TEST SPECIMENTS:

The portland cements were first passed thru a No. 20 sieve and then placed in moisture proof bins and marked. Part of each was used to make the standard tests. The remainder was screened on a No. 200 sieve and used in the blended cements as the work progressed. A series of 27 tension briquettes was then made from each of the standard portland cements passing the No. 20 sieve. This was followed by making 27 tension briquettes of each blended cement; one series contained 90 percent of the active particles and 10 percent of the blend; another 80 percent of active particles and 20 percent of the blend; a third of 70 percent of the active particles and 30 percent of the blend; and the last of 60 percent of active particles and 40 percent of blend. Likewise a series of 24 tension briquettes containing 25 percent of the portland cement passing the No. 20 sieve and 75 percent of standard Ottawa sand by weight were made from

each kind of portland cement. This was followed by four series of 24 tension briquettes containing 25 percent of the blended cements as mentioned above and 75 percent by weight of the Ottawa standard sand. The series containing none of the standard sand will be called neat briquettes and those containing the sand will be called mortar briquettes. From the above it will be seen that 405 neat briquettes and 360 mortar briquettes were made.

A like series of compression cylinders two inches in diameter and two inches high was then made. The percentages in the neat and mortar compression cylinders were the same as in the neat and mortar tension briquettes, but only 15 specimens were made of each series. The number of neat and mortar cylinders made was 215 each, making a total of 1195 test specimens.

TESTS:

The following tests were made:

(1) Normal consistancy.

This test was made on each portland cement and each blended cement.

(2) Time of Set.

This test was made on each portland cement and each blended cement.

(3) Constancy of volume.

This test was also made on each portland cement and each blended cement.

(4) Tension tests:

Tension tests were made on both the so-called neat cement and the mortar briquetts as follows:

On neat cement briquetts.

(a) 24 hour.

(b) 7 day.

(c) 28 day.

(d) 56 day.

(e) 84 day.

On mortar briquetts.

(a) 7 day.

(b) 28 day.

(c) 56 day.

(d) 84 day.

Note:

Enough briquetts were made to have three for each test. Also enough were made to make a six month, a nine month and a two year test on each, but these tests cannot be recorded in this report.

(5) Compression tests:

Compression tests were made on both the neat cement and mortar cylinders, which were two inches in diameter and two inches high, as follows:

On neat cement cylinders.

(a) 28 day.

(b) 84 day.

On mortar cylinders.

(a) 28 day.

(b) 84 day.

Note:

The same note applies here as is written under the heading "Tension tests."

(6) Specific gravity tests:

The specific gravity of each portland and blended cement was determined.

In all tests the standard methods and specifications as recommended by the Association of American Portland Cement Manufacturers were followed.

Besides these tests a sieve analysis and a chemical analysis of each cement was made; a sieve analysis of the blend was also made.

SYMBOLS USED:

Throughout this report the following letters will be used to designate the portland cements and blended cements.

A - Atlas portland cement.

B - Lehigh portland cement.

C - Red Ring portland cement.

The lower case letters refer to the portland cement from which the active particles have been taken, and the numeral following the letter is the percentage of blend that was used with the active particles to produce the blend cement. Thus "a" refers to the active particles taken from the Atlas portland cement, and 10 is the percent of blend used to make the blended cement. The resulting blended cement would then be designated as a10.

RESULTS.

(1) Normal Constancy.

(a) For neat cement briquettes.

Series	Per cent	Series	Per cent	Series	Per cent
A	22.0	B	21.0	C	21.5
a10	26.0	b10	24.0	c10	25.0
a20	23.0	b20	22.5	c20	23.5
a30	22.5	b30	22.0	c30	22.5
a40	21.5	b40	21.0	c40	21.5

(b) For mortar briquettes.

Series	Per cent	Series	Per cent	Series	Per cent
A	10.2	B	10.0	C	10.1
a10	10.8	b10	10.5	c10	10.7
a20	10.3	b20	10.25	c20	10.4
a30	10.25	b30	10.2	c30	10.25
a40	10.1	b40	9.9	c40	10.1

(2) Time of Set.

Series	Initial Set.	Final Set.
A	2hr & 50 mi.	5hr & 20 mi.
a10	00hr & 20 mi.	5hr & 10 mi.
a20	1hr & 35 Mi.	5hr & 30 mi.
a30	4hr & 40 mi.	8hr & 30 mi.
a40	5hr & 00mi.	6hr & 25 mi.
B	4hr & 55 Mi.	9hr & 00 Mi.
b10	3hr & 15 Mi.	6hr & 20 mi.
b20	2hr & 15 mi.	5hr & 50 mi.
b30	6hr & 45Mi.	9hr & 35 mi.
b40	7hr & 35 mi.	10hr & 15 mi.
C	3hr & 50 mi.	5hr & 55mi.
c10	3hr & 45 mi.	6hr & 00mi.
c20	4hr & 35 mi.	8hr & 10 mi.
c30	5hr & 00 mi.	7hr & 25 mi.
c40	4hr & 55mi.	7hr & 25 mi.

(3) Constancy of Volume.

The constancy of volume was o.k. throughout. Each pat either steamed, kept under water or kept in the open air did not disintegrate. The steam balls also showed no tendencies of disintegrating.

(4) Tension Tests.

(a) Neat Briquettes.

Series	Avg. stress per sq.in. at end of				
	24 hrs.	7 Days	28 Days	56 Days	84 Days.
A	317	779	855	758	789
a10	322	537	682	666	711
a20	243	752	695	738	773
a30	278	657	771	816	762
a40	310	662	754	748	771
B	306	815	821	801	883
b10	366	666	699	792	708
b20	332	733	860	753	792
b30	259	651	763	774	702
b40	191	547	655	777	711
C	393	686	779	758	745
c10	301	630	758	700	681
c20	306	590	622	614	703
c30	178	591	607	711	607
c40	200	511	637	706	644

(b) Mortar Briquettes.

Series.	Avg. stress per sq.in. at end of			
	7 Days	28 Days	56Days	84 Days.
A	186	289	325	346
a10	338	427	461	508
a20	272	405	459	417
a30	225	358	394	440
a40	202	341	360	373
B	197	339	369	384
b10	297	425	445	461
b20	277	418	423	448
b30	249	334	396	414
b40	195	321	343	372
C	232	374	383	471
c10	274	322	383	461
c20	266	422	418	462
c30	258	362	408	414
c40	195	365	359	407

(5) Compression Tests.

Avg. stress per sq.in. at end of

Series	Neat Briquettes		Mortar Briquettes.	
	28 days	84 days	28 days	84 days.
A	6180	7840	3700	
a10	6120	8000	3370	
a20	7400	7670	3150	
a30	6325	6400	2100	
a40	5650		1830	
B	6360	8250	3400	
b10	6225	10030	2850	
b20	6375	6970	3000	
b30	6340	6160	2210	
b40	6280		1925	
C	5580	7330	3900	
c10	5880	7600	2910	
c20	8100	5900	2660	
c30	5640	7050	1580	
c40	5450		1583	

(6) Specific Gravity.

The specific gravity on each standard portland cement and the blend was made as is required by the standard specifications of the American Portland Cement Manufacturers. The specific gravity of the blended cements were then figured from these results.

Series	Sp. Gr.	Series	Sp. Gr.	Series	Sp. Gr.	Series	Sp. Gr.
Blend	2.681	a30	3.033	b20	3.076	c10	3.155
A	3.184	a40	2.984	b30	3.028	c20	3.102
a10	3.135	B	3.176	b40	2.977	c30	3.049
a20	3.084	b10	3.126	C	3.208	c40	2.996

(7) Chemical analysis.

The chemical analysis on each standard portland cement and the blend was made in the chemical laboratory as required by the standard specifications of the American Portland Cement Manufacturers. The chemical analysis of the blended cements were then figured from these results.

Percentages of

Series	Ignit- ion Loss	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	SO ₃	Total.
Blend	0.32	98.66	0.31	0.69	0.04	—	—	100.02
A	1.80	21.98	2.57	5.89	63.32	3.00	1.50	100.06
a10	1.60	29.64	2.28	5.30	56.97	2.70	1.35	99.90
a20	1.50	37.31	2.02	4.86	50.66	2.40	1.20	99.95
a30	1.35	44.88	1.89	4.33	44.33	2.10	1.05	99.93
a40	1.21	52.65	1.66	3.81	38.01	1.80	0.90	100.04
B	1.80	21.46	2.85	6.81	63.56	2.10	1.46	100.03
b10	1.65	29.18	2.59	6.20	57.21	1.89	1.31	100.03
b20	1.50	36.90	2.31	5.58	50.85	1.68	1.17	99.99
b30	1.35	44.62	2.09	4.97	44.40	1.47	1.02	100.01
b40	1.21	52.32	1.83	4.36	38.14	1.26	0.87	99.99
C	0.60	22.70	3.07	7.55	63.18	1.22	1.53	99.85
c10	0.57	30.08	2.79	6.87	56.80	1.09	1.37	99.57
c20	0.54	37.88	2.51	6.18	50.61	0.97	1.22	99.91
c30	0.52	45.49	2.24	5.49	44.21	0.85	1.07	99.87
c40	0.49	53.08	1.96	4.81	37.91	0.73	0.91	99.89

(8) Sieve Analysis.

A sieve analysis was only made on the standard portland cements and the blend. The amount used was 1000 grams in each case.

Retained on sieve.	Blend	A	B	C
No. 35	0.60%	0.05%	0.00%	0.15%
No. 48	1.20%	0.05%	0.01%	0.20%
No. 65	3.30%	0.60%	0.75%	0.50%
No. 100	11.25%	2.90%	4.48%	2.09%
No. 150	39.50%	9.40%	11.96%	9.84%
No. 200	26.20%	9.00%	6.90%	8.42%
passing No. 200	17.85%	78.00%	75.90%	78.80%
Total	99.90%	100.00%	100.00%	100.00%

DISCUSSION OF RESULTS
AND
CONCLUSIONS.

DISCUSSION OF RESULTS:

From the time value curves of the neat tension briquettes it will be noticed that, at the end of 84 days, none of the blended cement briquettes were as strong as those made from the standard portland cements; but on the contrary in the mortar briquettes the blended cements are in general stronger. This is especially noticeable in the mortar briquettes of blended cements made from the Atlas and Lehigh portland cements; but in those made from the Red Ring portland cement only the clo increase while the remainder decreased. In all the compression tests there was a decrease in strength in all blended cement cylinders either neat or mortar.

This is indeed unfavorable, for, if the same results were found in tests on concrete cylinders, it would be unwise to use blended cements, because a slight increase in tensile strength would be of no benefit and a decrease in compressive strength would weaken the one good quality of concrete.

CONCLUSIONS:

There were no disintegrating tendencies and the time of set although it shortened in a

few cases lengthened in the majority of the series thereby producing the two of the desired results. The tensil strength decreased in the neat briquettes and increased in the majority of the tests in mortar briquettes. The compressive strength decreased in all tests.

A P P E N D I X.
(Tabulated Results & Curves.)

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (A) Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.184	22.0	3.6	22% 10.2%	2h & 50m	5h & 20m	O.K.	O.K.	O.K.	O.K.
-25-	Tensile Strength. Neat Cement Briquettes.					Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.			
24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
295	317	743	779	843	855	192	186	257	289
343		826		861		165		288	
312		768		861		200		322	
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		769	758	755	789	340	325	339	346
		773		728		322		343	
		722		875		314		357	

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (B) Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.				
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.		
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.	
3.176	81.8	6.10	21% 10%	4h & 55m	9hrs.	O.K.	O.K.	O.K.	O.K.	
Tensile Strength. Neat Cement Briquettes.					Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.					
24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average	
311	306	797	815	802	821	192	197	332	339	
325		812		784		175		348		
282		835		878		224		339		
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.	
				802		912		345		389
			801	943	883	381	369	402	384	
				815		784		383		361

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (C) Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.208	21.2%	2.04%	21½% 10.1%	3h & 50m	5h & 55m	O.K.	O.K.	O.K.	O.K.
-27-	Tensile Strength. Neat Cement Briquettes.					Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.			
24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
400	393	710	686	758	779	213	232	362	374
405		612		790		228		366	
375		745		789		254		395	
Remarks :		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		758	758	711	745	392	382	462	471
		727		737		387		466	
		788		788		369		485	

Tested by _____

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (A - 10) Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.125			26% 10.8	20 min	5h & 10m	O.K.	O.K.	O.K.	O.K.

Tensile Strength. Neat Cement Briquettes.					Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.				
24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average.
325	322	637	537	635	682	334	338	462	427
332		463		674		337		443	
308		512		738		343		375	
Remarks :		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
#Omit.		677	666	679	711	527	461	524	508
		#		736		428		476	
		656		719		428		523	

Tested by _____

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (b - 10) _____ Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.077			24% 10.5%	3h & 15m	6h & 20m	O.K.	O.K.	O.K.	O.K.
-29-	Tensile Strength. Neat Cement Briquettes.					Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.			
24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
388	366	544	666	645	699	311	297	413	425
370		721		753		294		366	
340		712		#		285		496	
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		791	792	714	708	412	445	449	461
		793		761		426		447	
#Omit.		790		651		522		487	

Tested by _____

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (o - 10) _____ Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.143			25% 19.7%	3h & 45m	6 hrs.	O.K.	O.K.	O.K.	O.K.

- 50 -
Tensile Strength.
Neat Cement Briquettes.

Tensile Strength.
Mortar Briquettes { 1 Part Cement
3 Parts Ottawa Sand.

24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
320	301	521	630	765	758	320	274	325	322
295		648		751		230		304	
288		720		#		273		337	
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		662	700	686	681	351	383	457	461
#Omit.		724		688		414		511	
		713		670		#		416	

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (a - 20) Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.083			23% 10.3%	1h & 35m	5h & 30m	O.K.	O.K.	O.K.	O.K.

-31-

Tensile Strength. Neat Cement Briquettes.

Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.

24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
235	253	777	752	755	715	308	272	417	405
274		733		#		252		404	
220		745		675		257		396	
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
#Omit		745	738	763	773	475	459	389	417
		680		764		448		404	
		789		792		453		458	

Tested by _____

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (b- 20) _____ Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.077			22½% 10.25%	2h & 15m	5h & 50m	O.K.	O.K.	O.K.	O.K.
-32-	Tensile Strength. Neat Cement Briquettes.					Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.			
24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
323	332	716	733	900	859	284	277	422	418
364		726		902		299		405	
320		759		777		248		428	
Remarks:		56 Day	Avg. 753	84 Day	Avg. 792	56 Day	Avg. 432	84 Day	Avg. 448
		750		784		430		408	
		662		796		400		476	
		794		797		439		462	

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (C - 20) _____ Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.102			23½% 10.4%	4h & 35m	8h & 10m	O.K.	O.K.	O.K.	O.K.

Tensile Strength.
Neat Cement Briquettes.

Tensile Strength.
Mortar Briquettes { 1 Part Cement
3 Parts Ottawa Sand.

24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
327	306	561	590	#	622	273	266	460	422
314		603		613		257		416	
277		607		652		268		381	
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		620		714		373		426	
#Omit		623	614	672	703	427	418	491	462
		600		724		455		468	

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (a - 30) _____ Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.033			22.5% 10.25%	4h & 40m	8h & 30m	O.K.	O.K.	O.K.	O.K.

-34-

Tensile Strength. Neat Cement Briquettes.

Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.

24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
225	278	622	657	744	771	220	225	381	358
303		680		820		220		367	
305		670		750		237		327	
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		872	816	747	762	400	393	484	440
		865		777		350		426	
		812		674		431		411	

Tested by _____

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (b- 30) Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
3.028			22.0% 10.2%	5h & 45m	9h & 35m	O.K.	O.K.	O.K.	O.K.
-35-	Tensile Strength. Neat Cement Briquettes.					Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.			
24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
249	259	630	651	797	763	252	248	306	334
272		730		731		232		346	
255		593		782		262		350	
Remarks :		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		714	774	720	702	409	396	429	413
		830		688		344		361	
		778		700		435		451	

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (C - 30) _____ Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
3.049			22.5% 10.25%	5h & 00m	7h & 25m	Air 28 Days O.K.	Water 28 Days O.K.	Steamed 5 Hrs. O.K.	Boiled 3 Hrs. O.K.

- 56 -

Tensile Strength. Neat Cement Briquettes.

Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.

24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
182	178	579	591	664	607	248	258	365	362
177		559		544		260		382	
175		634		615		267		340	
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		784	711	577	607	346	408	444	414
		730		627		476		414	
		620		618		402		385	

Tested by _____

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (a - 40) Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		*Constancy of Volume.				
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.		
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.	
2.984			21 1/2% 10.1%	5h 3m	6h 25m	O.K.	O.K.	O.K.	O.K.	
Tensile Strength. Neat Cement Briquettes.					Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.					
-37-	24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
	325	310	#	662	777	754	181	201	356	341
	300		629		791		221		339	
	305		694		693		203		328	
Remarks:		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.	
#Omit		767	748	797	771	371	360	381	373	
		759		725		356		364		
		719		793		354		302		

Tested by _____

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (b - 40) Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
2.977			21.0% 9.9%	7h 35m	10h 15m	O.K.	O.K.	O.K.	O.K.

- 33 -

Tensile Strength. Neat Cement Briquettes.

Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.

24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
265	191	583	547	651	655	187	194	318	321
#		482		685		194		338	
117		576		631		203		318	
Remarks :		56 Day	Avg.	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
# Omit		735	777	748	711	308	343	372	372
		775		705		358		332	
		820		682		362		403	

Tested by _____

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

CEMENT TEST REPORT

Date Tested _____

Sample from Car No. _____ Shipment Received Date _____

Brand of Cement (**C - 40**) _____ Number of Sacks Sampled _____ Number of Sacks in Shipment _____

Specific Gravity.	Fineness		Normal Consistency.	Time of Set.		Constancy of Volume.			
	Retained on No. 200	Retained on No. 100		Initial	Hard.	Normal		Accelerated.	
						Air 28 Days	Water 28 Days	Steamed 5 Hrs.	Boiled 3 Hrs.
2.996			21.½% 10.1%	4h 55m	7h 25m	O.K.	O.K.	O.K.	O.K.

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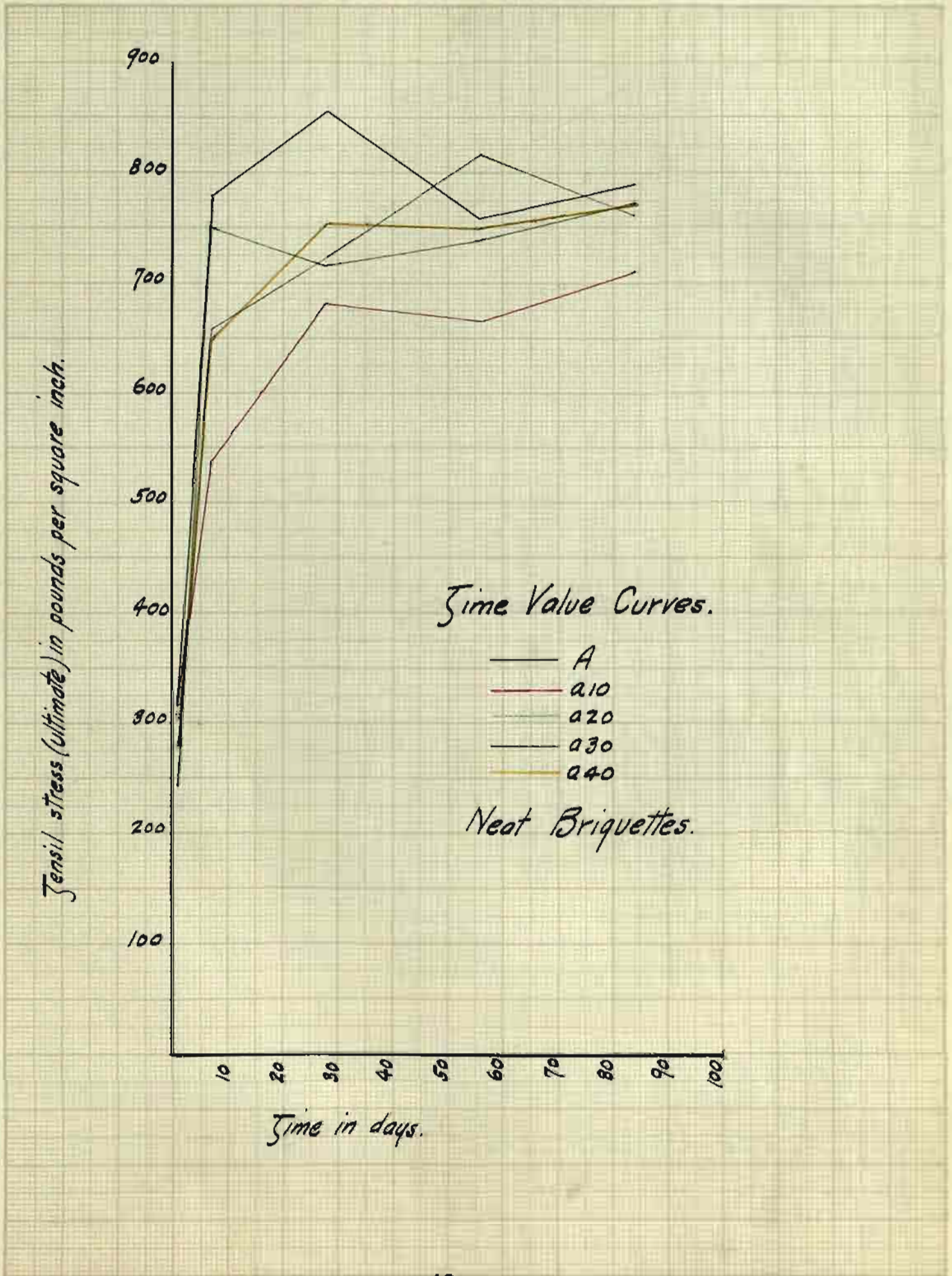
Tensile Strength. Neat Cement Briquettes.

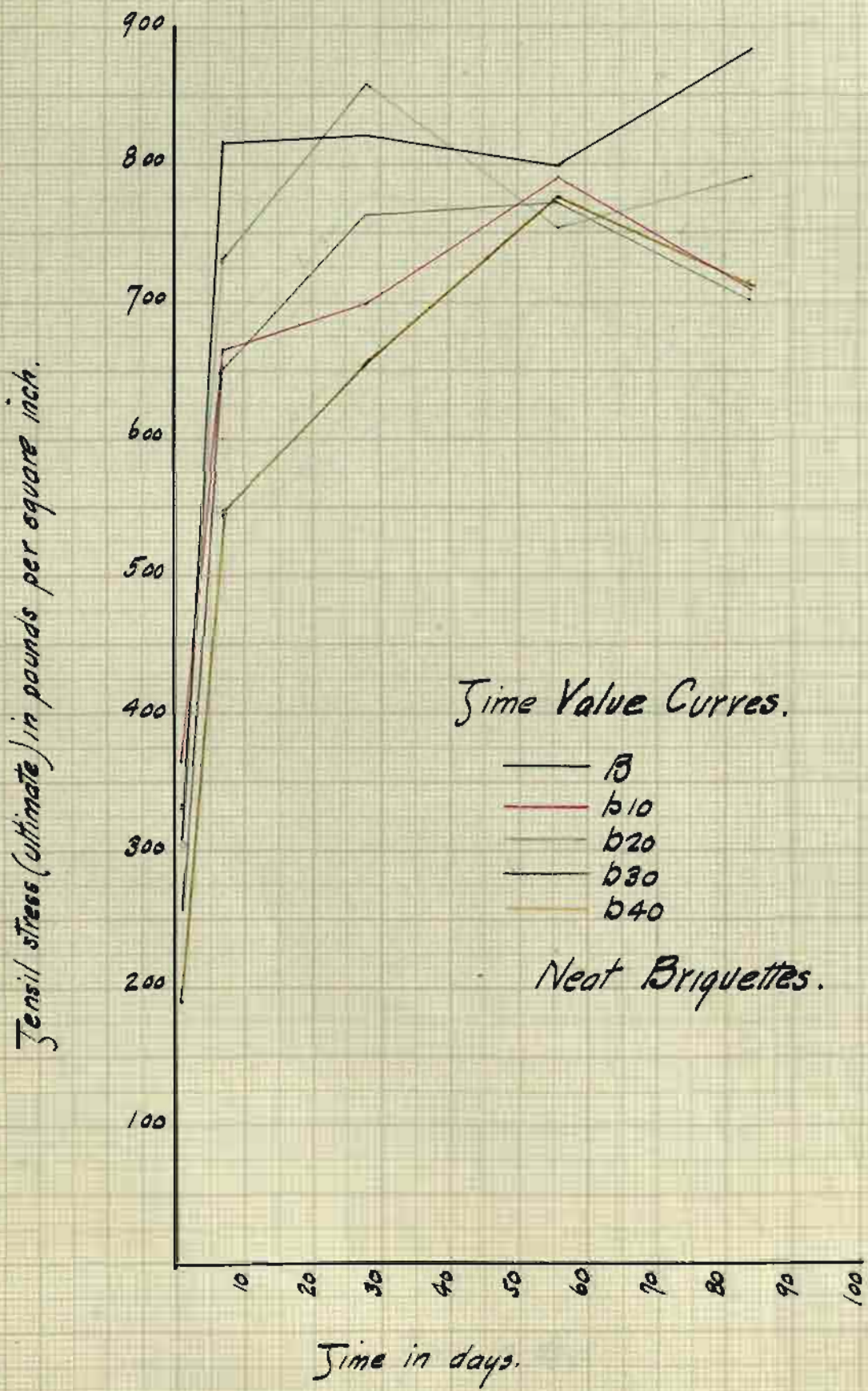
Tensile Strength. Mortar Briquettes { 1 Part Cement 3 Parts Ottawa Sand.

24 Hour	Average	7 Day	Average	28 Day	Average	7 Day	Average	28 Day	Average
186	200	525	511	560	637	181	194	382	365
208		525		678		218		362	
205		485		672		185		352	
Remarks :		56 Day	rAvg,	84 Day	Avg.	56 Day	Avg.	84 Day	Avg.
		730	706	628	644	342	359	421	407
		679		611		375		392	
		711		694		360		409	

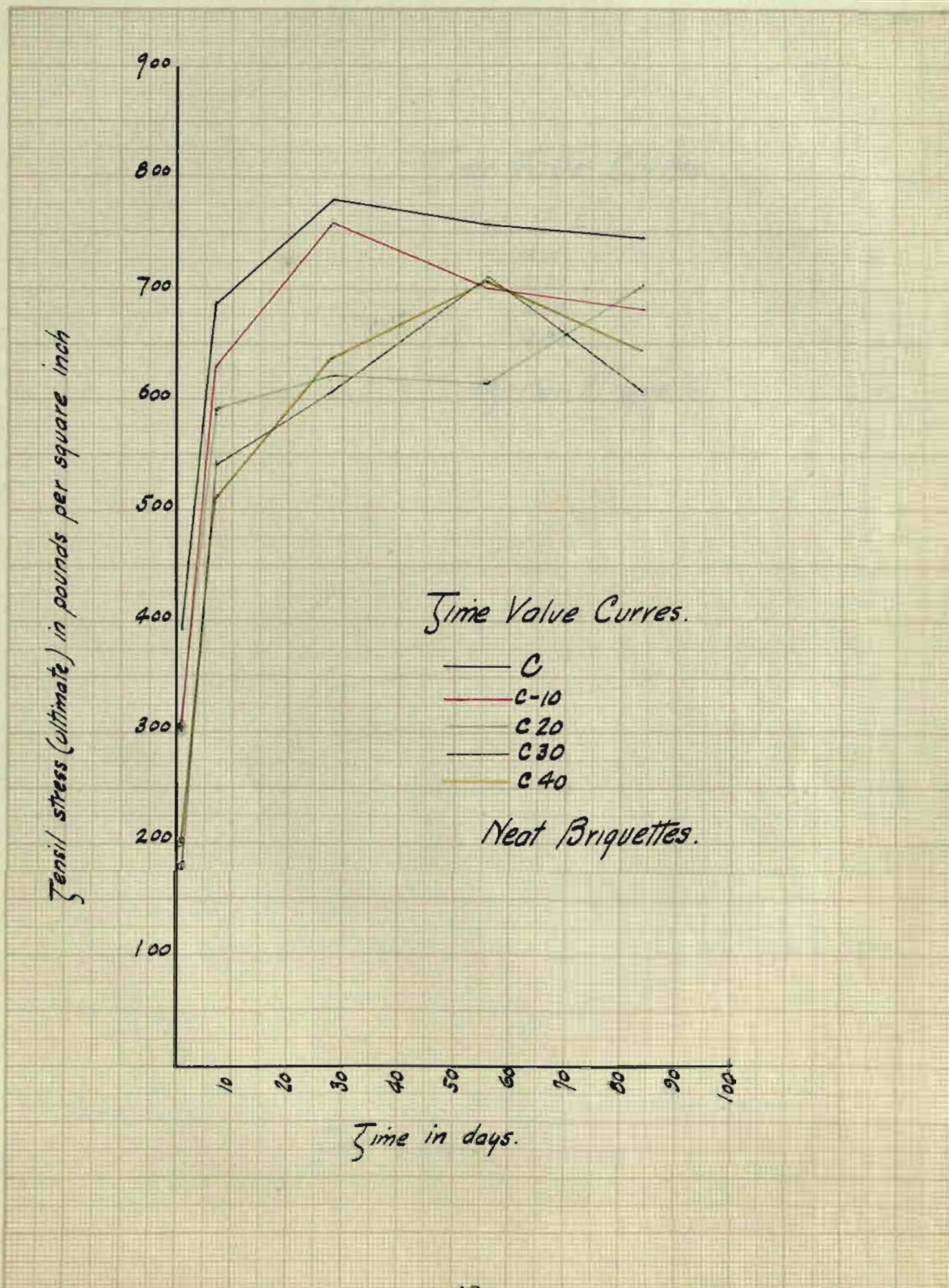
Tested by _____

MISSOURI SCHOOL OF MINES

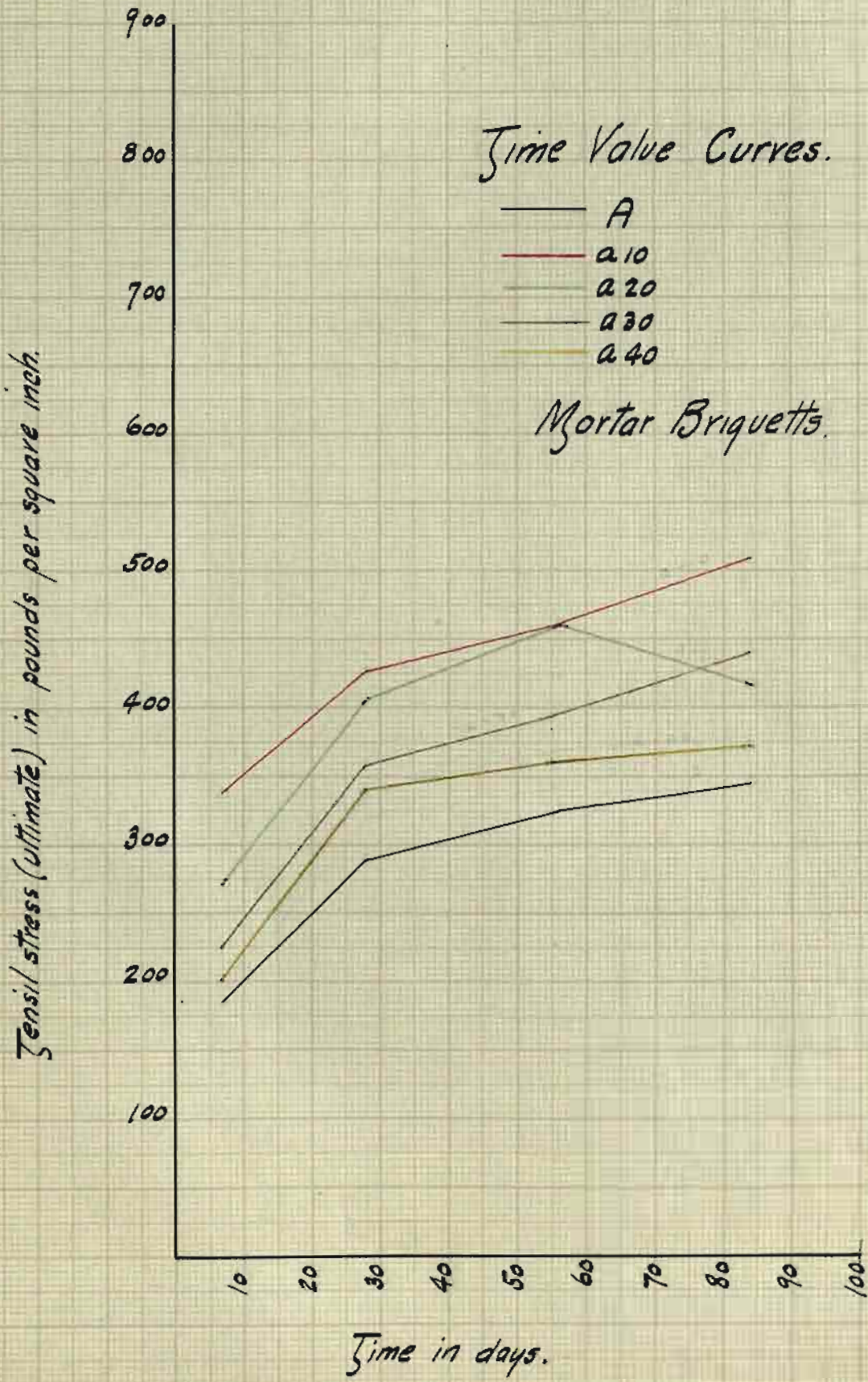




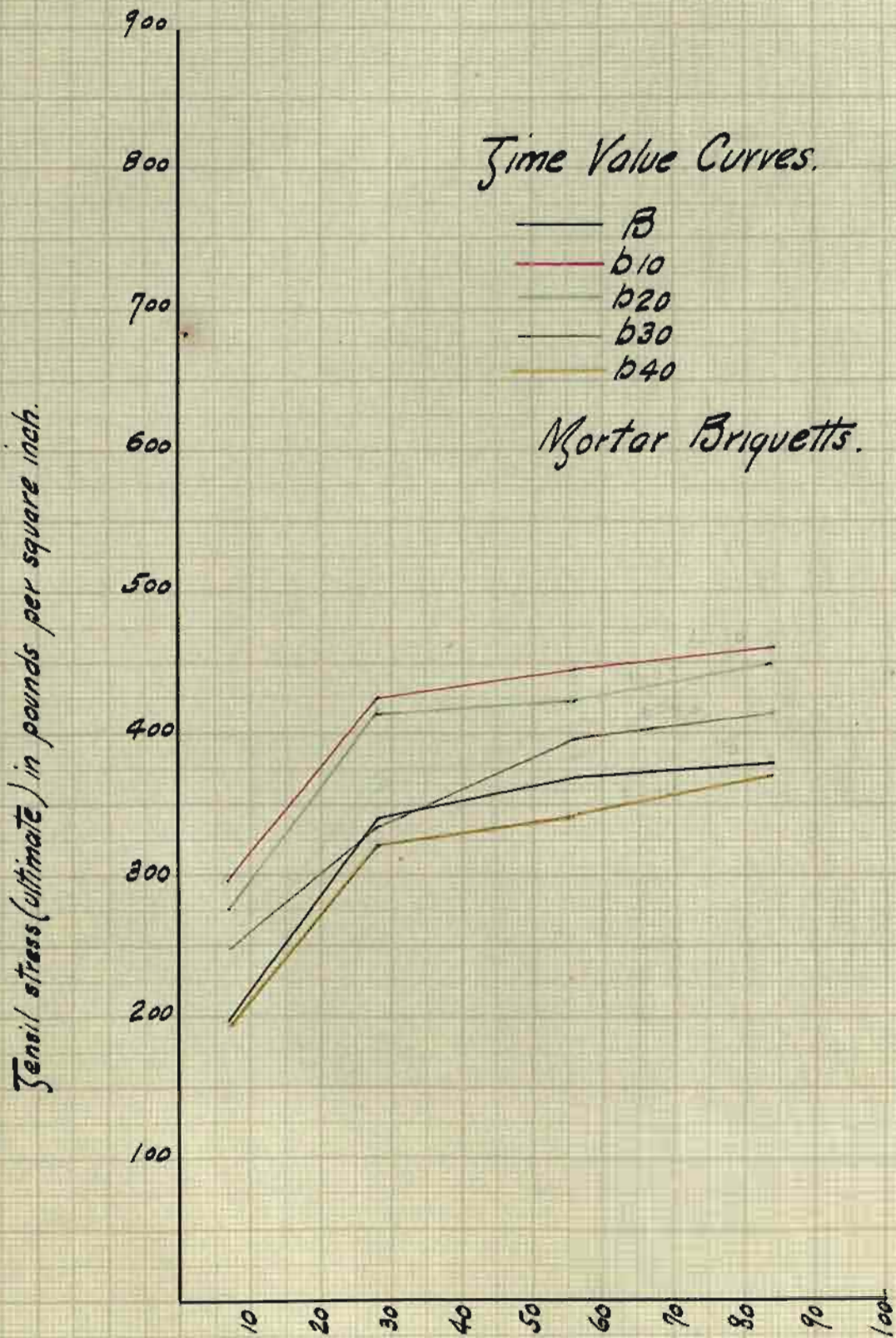
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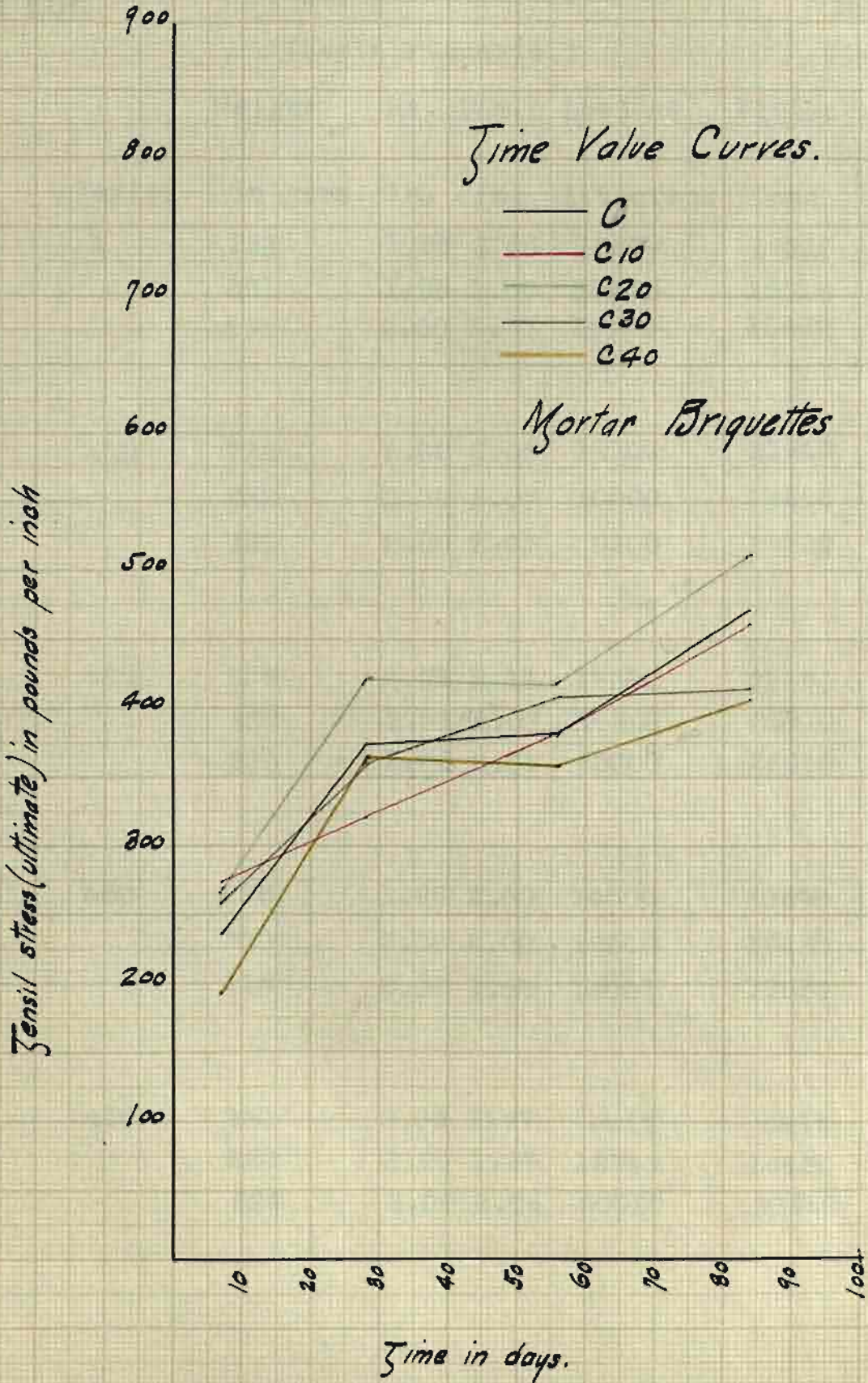
MISSOURI SCHOOL OF MINES



MISSOURI SCHOOL OF MINES



MISSOURI SCHOOL OF MINES



MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

RUNNING LOG

Compression Tests.

Exp't No.

(Neat Briquetts.)

Time 4 Weeks.

Series.	Weight in grms.	Ht. in.	Dia. in.	Load at 1st crack	Ultimate Load	Avg. ult. Load	Avg. ul Stress.
A	221	1.95	2.00	16500	17210		
	221	1.98	2.00	17470	22640		
	231	2.00	2.00	12700	18400	19417	6180
a10	232	2.02	2.06	11100	21940		
	232	2.08	2.07	10000	21600		
	225	2.00	2.03	9100	14200	19247	6120
a20	238	2.02	2.11	17500	21890		
	237	2.02	2.07	14500	21710		
	236	2.02	2.03	23000	26060	23220	7400
a30	228	1.98	2.00	14000	20590		
	230	2.00	2.00	12500	19430		
	218	2.00	1.98	14000	19630	19883	6325
a40	220	2.02	1.97	omit	omit		
	220	2.00	1.97	12940	14630		
	229	2.00	2.02	20920	20920	17775	5650

Date

Observers {

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

RUNNING LOG

Compression Tests

Exp't No.

(Neat Briquetts.)

Time 4 Weeks.

Series.	Weight in grms.	Ht. in.	Dia. in.	Load at 1st crack	Ultimate Load	Avg. ult. Load	Avg. Ult. Stress
B	231.5	2.00	2.00	14830	16550		
	231.5	2.00	2.00	17820	21500		
	232.0	2.00	2.00	13090	21930	19993	6360
b10	208	1.96	1.99	12860	19000		
	211	1.97	1.97	7000	19650		
	213	1.96	2.00	17500	20070	19573	6225
b20	215	2.01	1.97	13850	19680		
	214	2.02	1.96	14570	18420		
	216	2.03	1.96	20380	22100	20067	6375
b30	225	2.00	2.00	16800	21310		
	227	2.00	2.00	13700	19400		
	225	2.00	2.00	18700	19220	19977	6340
b40	219	2.01	1.99	21050	22000		
	229	2.02	2.02	17640	17640		
	227	2.00	2.02	19530	19530	19723	6280

Date

Observers {

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

RUNNING LOG

Compression Tests.

Exp't No.

(Neat Briquetts.)

Time: 4 Weeks.

Series.	Weight in grms.	Ht. in.	Dia. in.	Load at 1st crack	Ultimate Load	Avg. ult. Load	Avg. u. Stress
C	225	1.96	2.00	11100	14270		
	238	2.00	1.98	20740	20740		
	226	1.96	2.02	15670	17670	17560	5580
c10	235	2.05	2.05	15000	18150		
	236	2.03	2.05	12400	15370		
	237	2.07	2.05	13000	21970	18497	5880
c20	218	2.00	1.97	-----	29280		
	232	2.00	2.02	16000	23570		
	229	2.00	2.00	23460	23460	25437	8100
c30	227	2.00	2.00	13500	18260		
	221	2.01	1.98	14020	16500		
	226	2.02	2.00	17620	18400	17720	5640
c40	232	2.03	2.02	15060	15060		
	231	2.05	2.01	16900	17330		
	221#	2.02	1.99	17300	18990	17130	5450

broken on end.

Date

Observers }

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

RUNNING LOG

Compression Tests.

Exp't No.

(Mortar Briquetts.)

Time: 4 Weeks.

Series.	Weight in grms.	Ht. in.	Dia. in.	Load at 1st crack	Ultimate Load	Avg. ult. Load	Avg. ult. stress.
A	258	2.05	2.06	13060	13060		
	239	2.03	2.00	10560	10560		
	244	2.02	1.99	11240	11240	11620	3700
a10	240	2.08	2.00	9450	9450		
	256	2.10	2.02	10960	10960		
	254	2.09	2.02	11400	11400	10603	3370
a20	246	2.05	2.00	11000	12010		
	242	2.04	1.97	9000	9000		
	243	2.05	1.98	8690	8690	9900	3150
a30	236	2.09	1.98	7710	7710		
	254	2.09	2.03	5520	5520		
	243	2.10	2.00	6550	6550	6593	2100
a40	240	2.08	1.99	5090	5090		
	236	2.06	1.97	4760	4760		
	252	2.12	2.02	7420	7420	5760	1830

Date

Observers {

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

RUNNING LOG

Compression Tests.

Exp't No.

(Mortar Briquetts.)

Time: 4 Weeks.

Series.	Weight in grms.	Ht. in.	Dia. in.	Load at 1st crack	Ultimate Load	Avg. ult. Load.	Avg. ult. stress.
B	252	2.06	2.02	10240	10240		
	256	2.10	2.02	10830	10830		
	257	2.08	2.03	11970	11970	10680	3400
b10	235	2.05	2.00	7000	8500		
	233	2.04	1.99	9020	9020		
	247	2.05	2.04	9400	9400	8973	2850
b20	252	2.10	2.01	9650	9650		
	252	2.07	2.03	8900	8900		
	237	2.07	1.97	8000	8000	9517	3000
b30	241	2.10	1.98	7230	7230		
	251	2.10	2.00	7220	7220		
	254	2.12	2.02	6560	6560	7013	2210
b40	251	2.06	2.02	6100	6100		
	237	2.04	2.00	5520	5520		
	248	2.06	2.02	6550	6550	6057	1925

Date

Observers {

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

Compression Tests.

RUNNING LOG

(Mortar Briquetts.)

Exp't No.

Time: 4 Weeks.

Series.	Weight in grms.	Ht. in.	Dia. In.	Load at 1st crack	Ultimate Load.	Avg. ult. Load	Avg. ult. Stress.
C	258	2.10	2.02	12990	12990		
	260	2.10	2.04	12540	12540		
	254	2.09	2.01	11200	11200	12243	3900
c10	251	2.10	2.02	8520	8520		
	239	2.07	1.98	10210	10210		
	251	2.06	1.98	7710	7710	8815	2910
c20	249	2.06	2.03	—	—		
	241	2.06	1.98	5740#	5740#		
	236	2.05	2.03	5720	8380	8380	2660
c30	254	2.10	2.02	4950	4950		
	237	2.08	1.99	6030	6030		
	254	2.12	2.00	3930	3930	4970	1580
c40	247	2.08	2.02	3300	3300		
	250	2.08	2.03	5870	5870		
	234	2.05	1.98	4820	4820	4997	1583

poorly imbeded in plaster.

Date

Observers {

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

RUNNING LOG

Compression Tests.

Exp't No.

(Neat Briquetts.)

Time 12 Weeks.

Series.	Weight in grms.	Ht. in.	Dia. in.	Load at 1st crack	Ultimate Load.	Avg. ult. Load.	Avg. ult. stress
A	228	2.00	1.98	17200	19820		
	238	2.01	2.00	17250	22150		
	237	2.04	1.98	27240	27240	23070	7840
a10	234	2.04	2.02	8900	19950		
	235	2.05	2.04	21650	28070		
	219	2.00	2.00	9110	27330	25117	8000
a20	236	2.06	2.03	15400	20000		
	236	2.05	2.03	11300	22440		
	238	2.06	2.04	12100	29820	24086	7670
a30	220	2.00	1.97	9160	20240		
	219	2.00	1.98	10770	21150		
	234	2.02	2.00	8430	20490	20620	6400
a40							

Date

Observers {

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

Compression Tests.

(Neat Briquetts)

Exp't No.

Time 12 Weeks.

RUNNING LOG

Series.	Weight in grms.	Ht. in.	Dia. in.	Load at 1st crack	Ultimate Load.	Avg. ult. Load	Avg. ult. Stress.
B	234	2.00	1.97	31620	31620		
	237	2.02	1.98	20080	25800		
	236	2.00	1.97	12100	20410	25943	8250
b10	215	1.97	1.98	17460	33880		
	215	1.98	1.96	23870	30010		
	215	2.00	1.98	20010	33500	32463	10030
b20	230	2.04	2.02	7680	15350		
	216	2.03	1.99	19030	25540		
	217	2.04	1.98	15260	24830	21907	6970
b30	227	2.02	2.00	16460	21980		
	228	2.04	2.01	15970	22080		
	229	2.04	2.02	12100	14420	19393	6160
b40							

Date

Observers {

-53-

MATERIALS TESTING LABORATORY

MISSOURI SCHOOL OF MINES

RUNNING LOG

Compression Tests.

Exp't No.

(Neat Briquetts.)

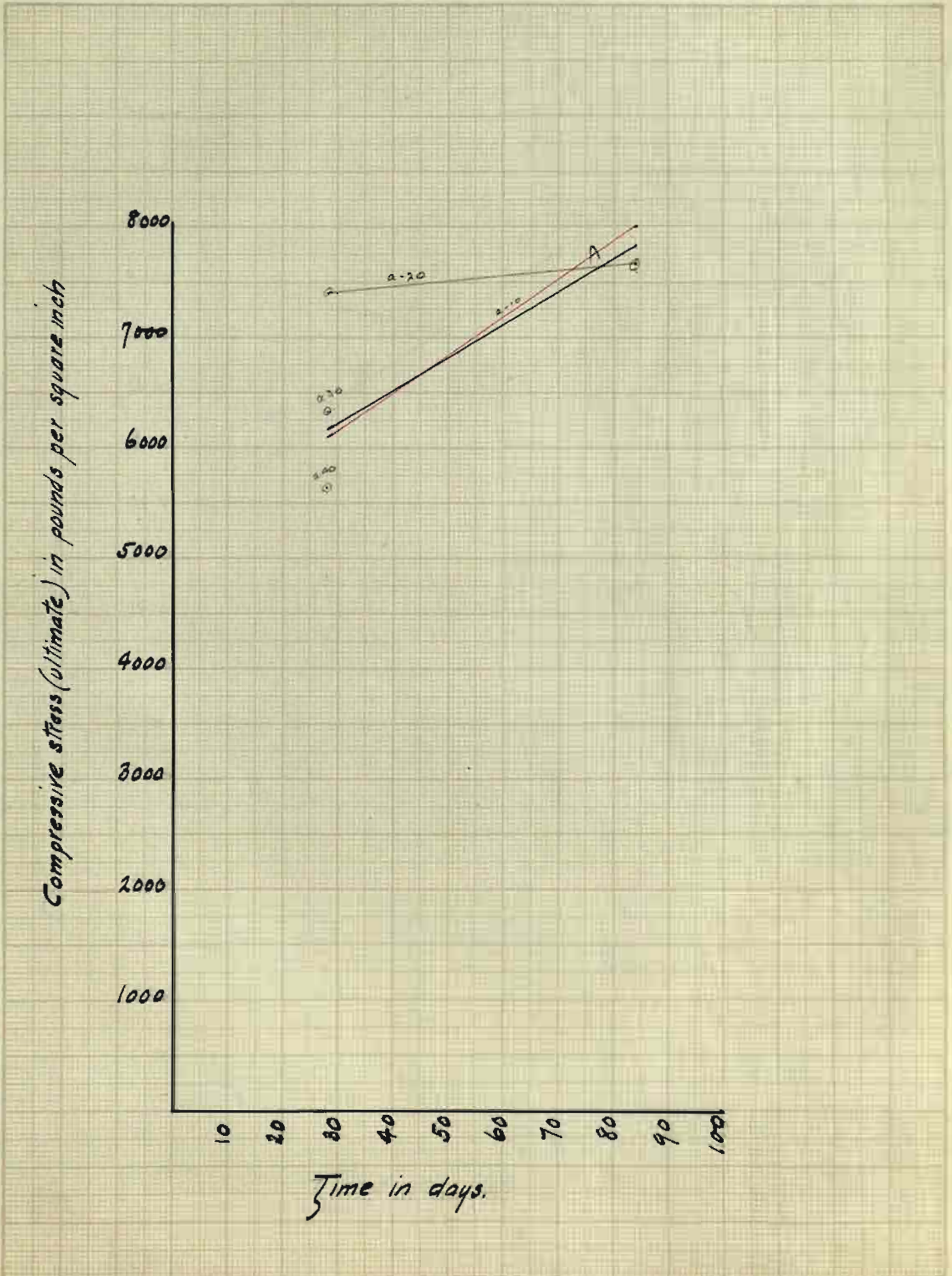
Time 12 Weeks.

Series.	Weight in grms.	Ht. in.	Dia. in.	Load at 1st crack	Ultimate Load	Avg. ult. Load	Avg. ul stress
C	227	2.00	1.98	12810	20910		
	224	1.98	1.96	13110	19540		
	229	2.00	1.96	17870	28610	23020	7330
c10	238	2.06	2.04	16710	26120		
	239	2.04	2.04	6470	20250		
	239	2.04	2.02	10640	25410	23927	7600
c20	222	2.01	1.98	14360	25340		
	221	2.00	2.00	9300	13060		
	219	1.99	1.99	14850	17140	18513	5900
c30	219	2.01	1.96	18110	18110		
	218	2.01	1.97	13550	23770		
	237	2.09	2.02	24710	24710	22196	7050
c40							

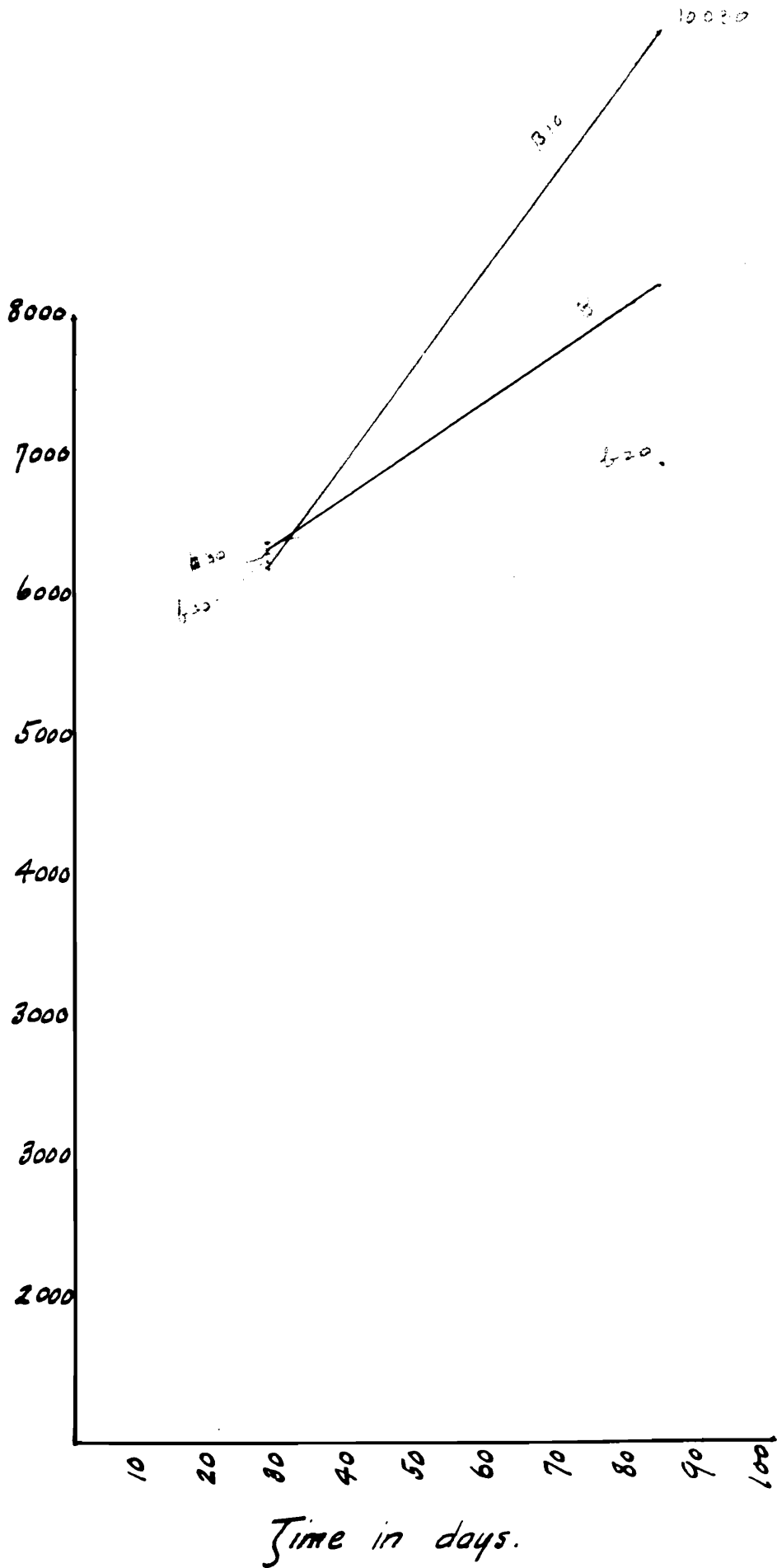
Date

Observers {

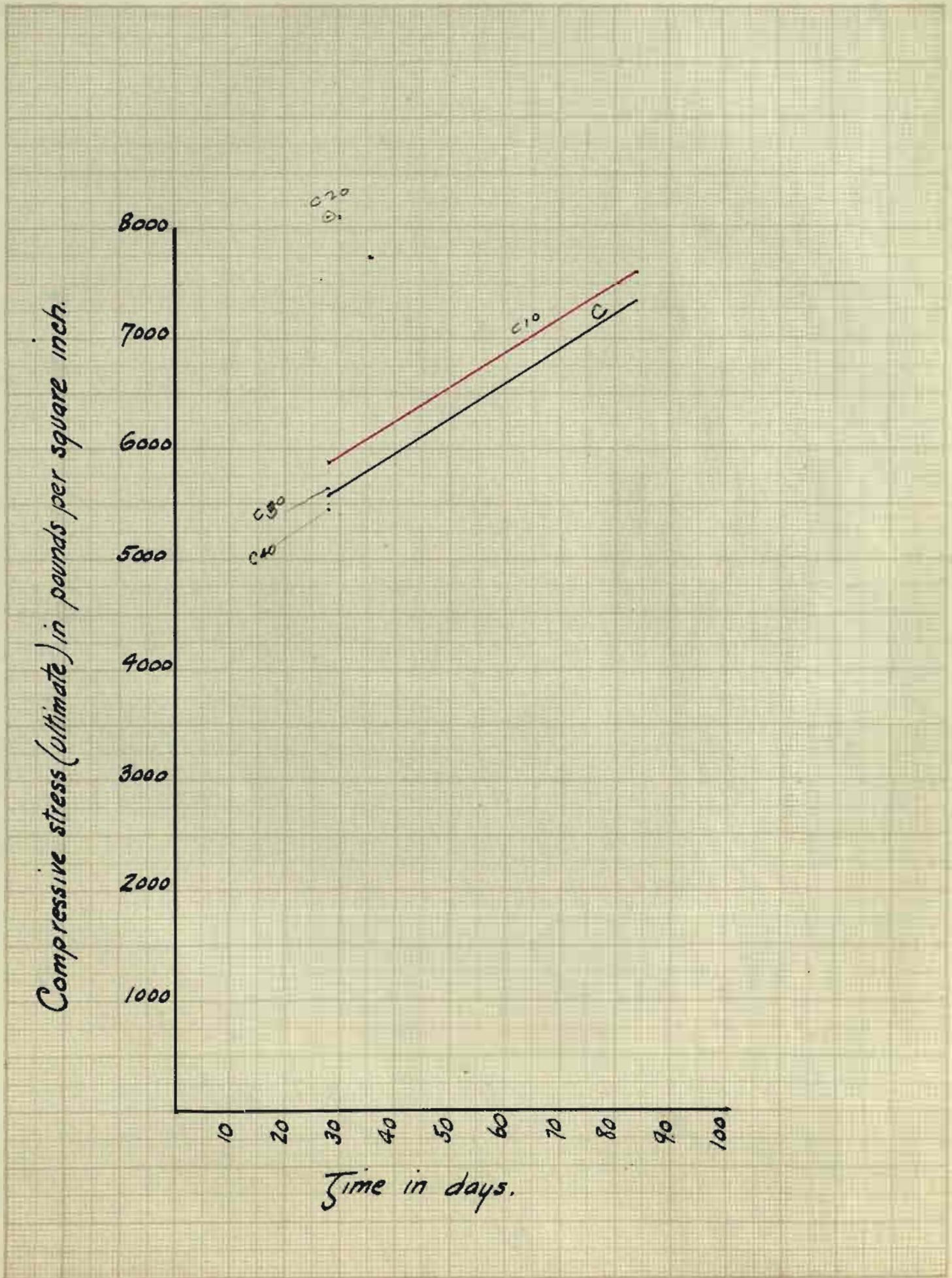
MISSOURI SCHOOL OF MINES



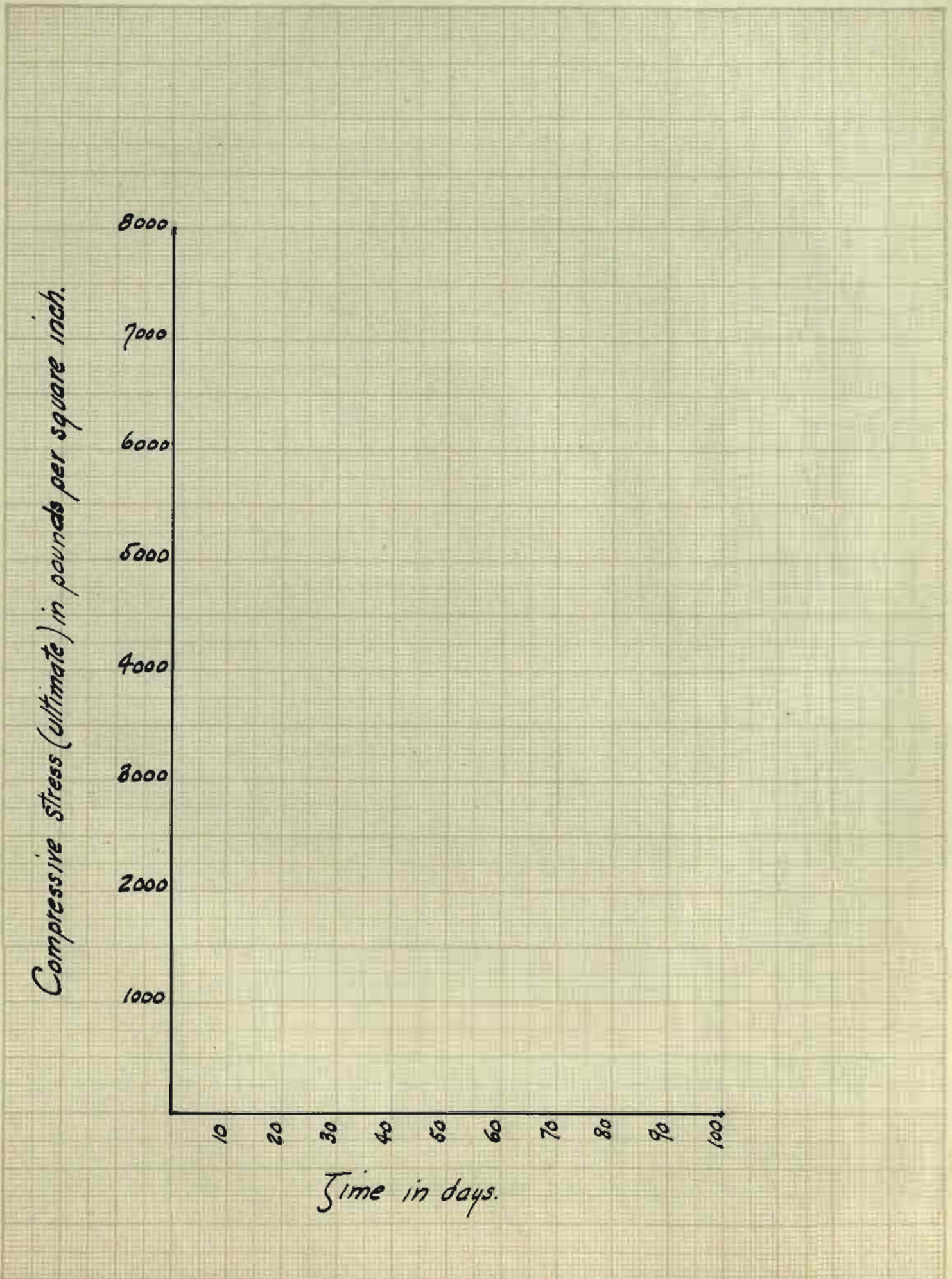
Compressive stress (ultimate) in pounds per square inch.



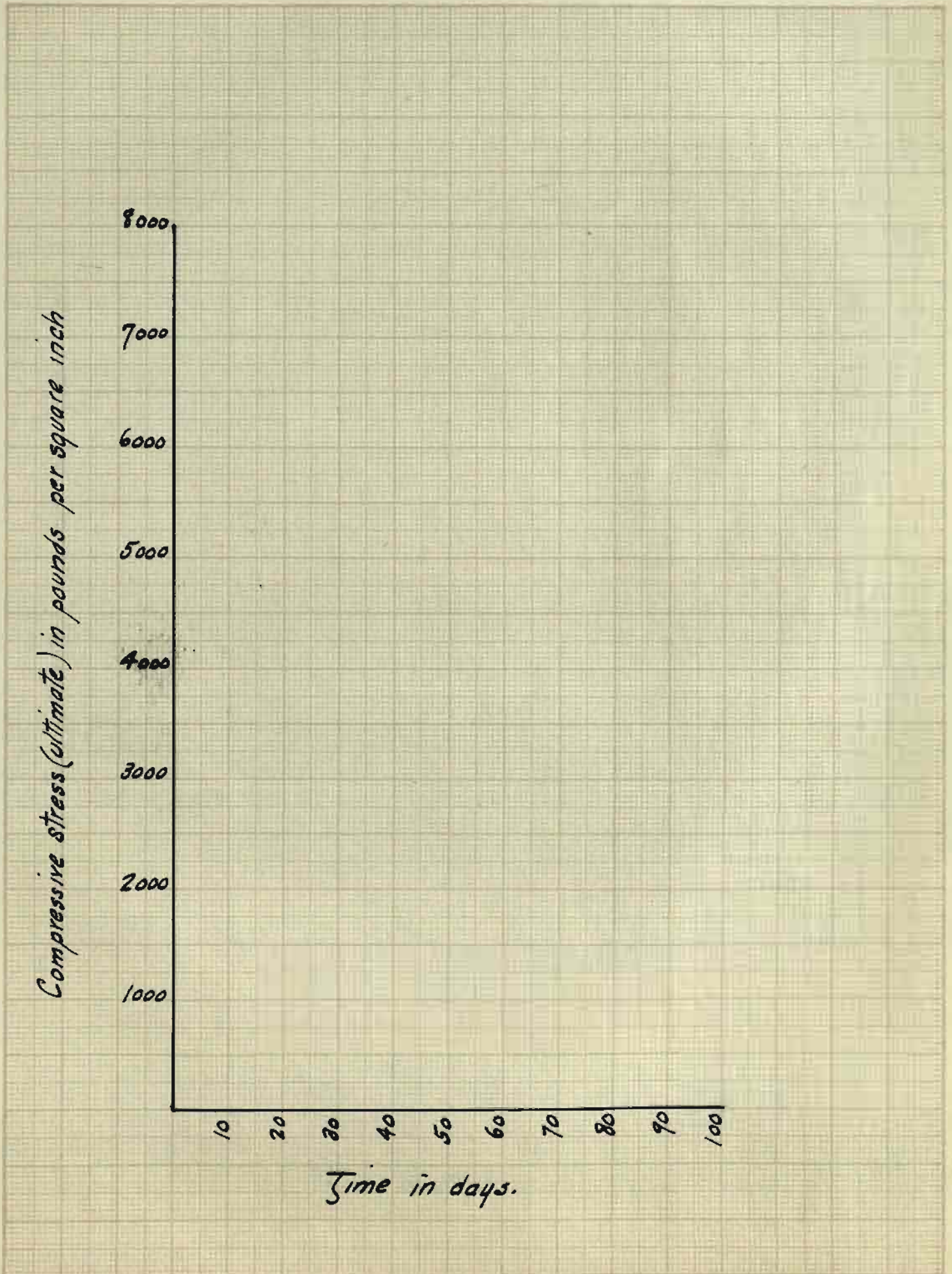
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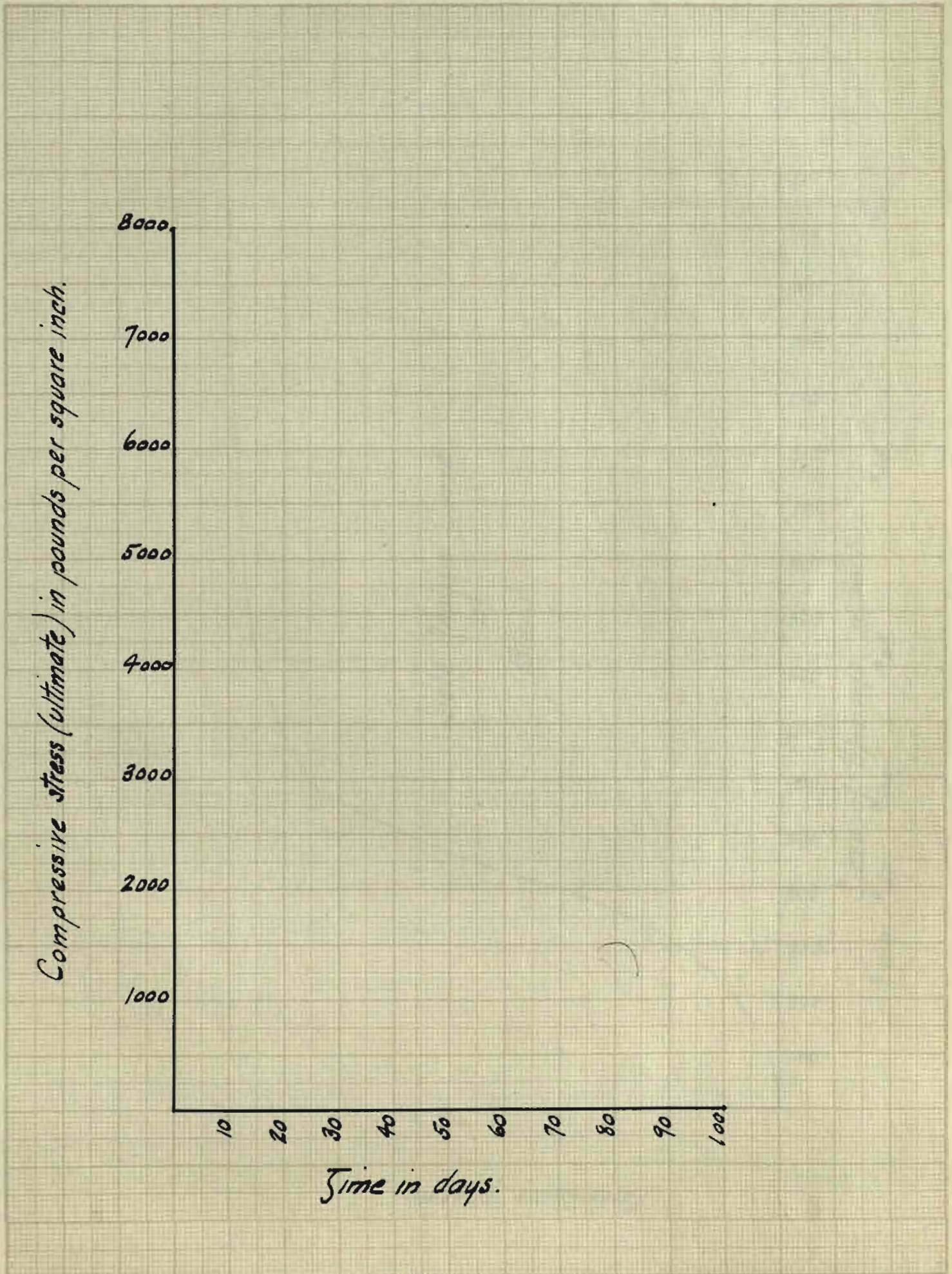
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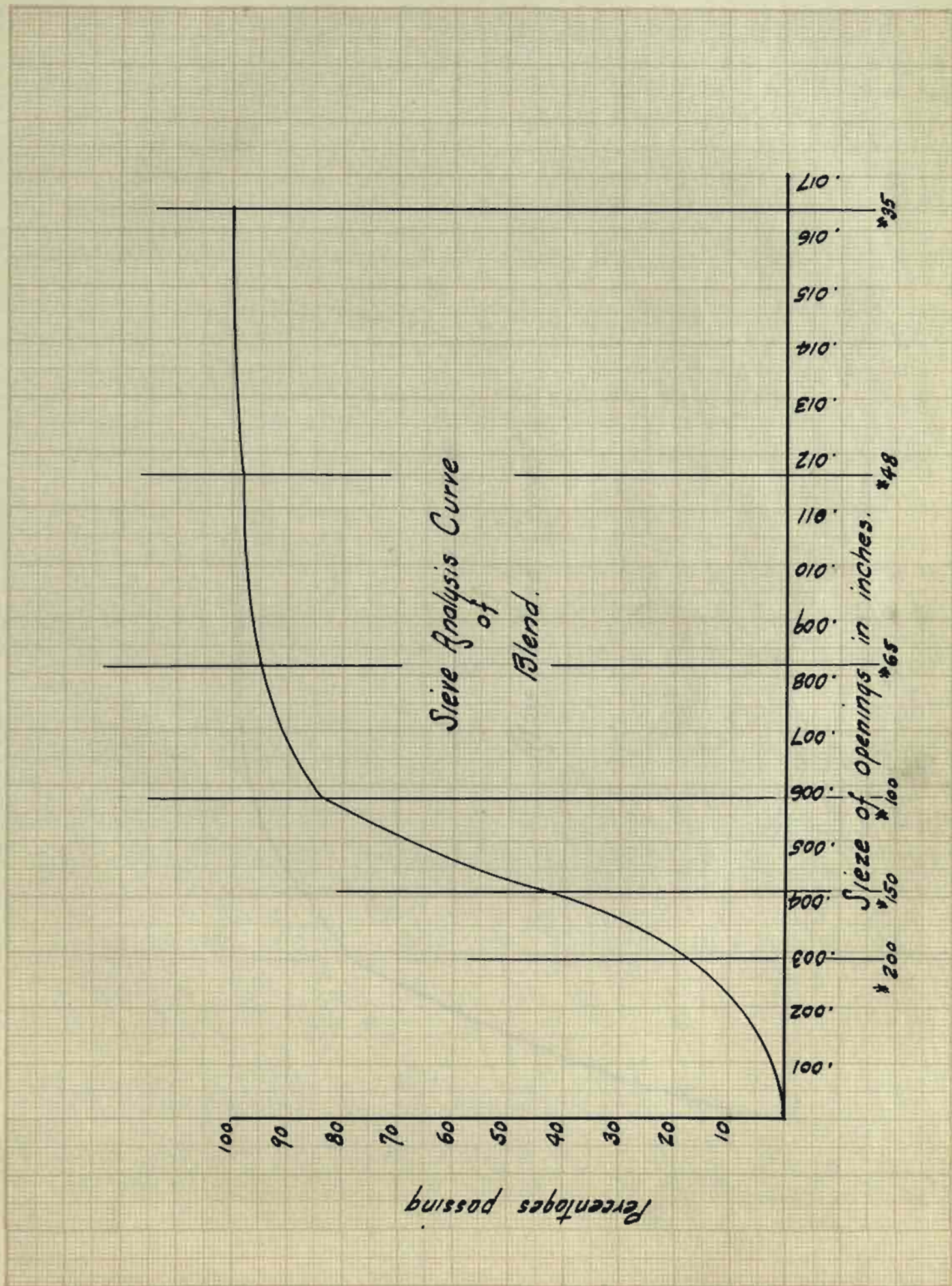
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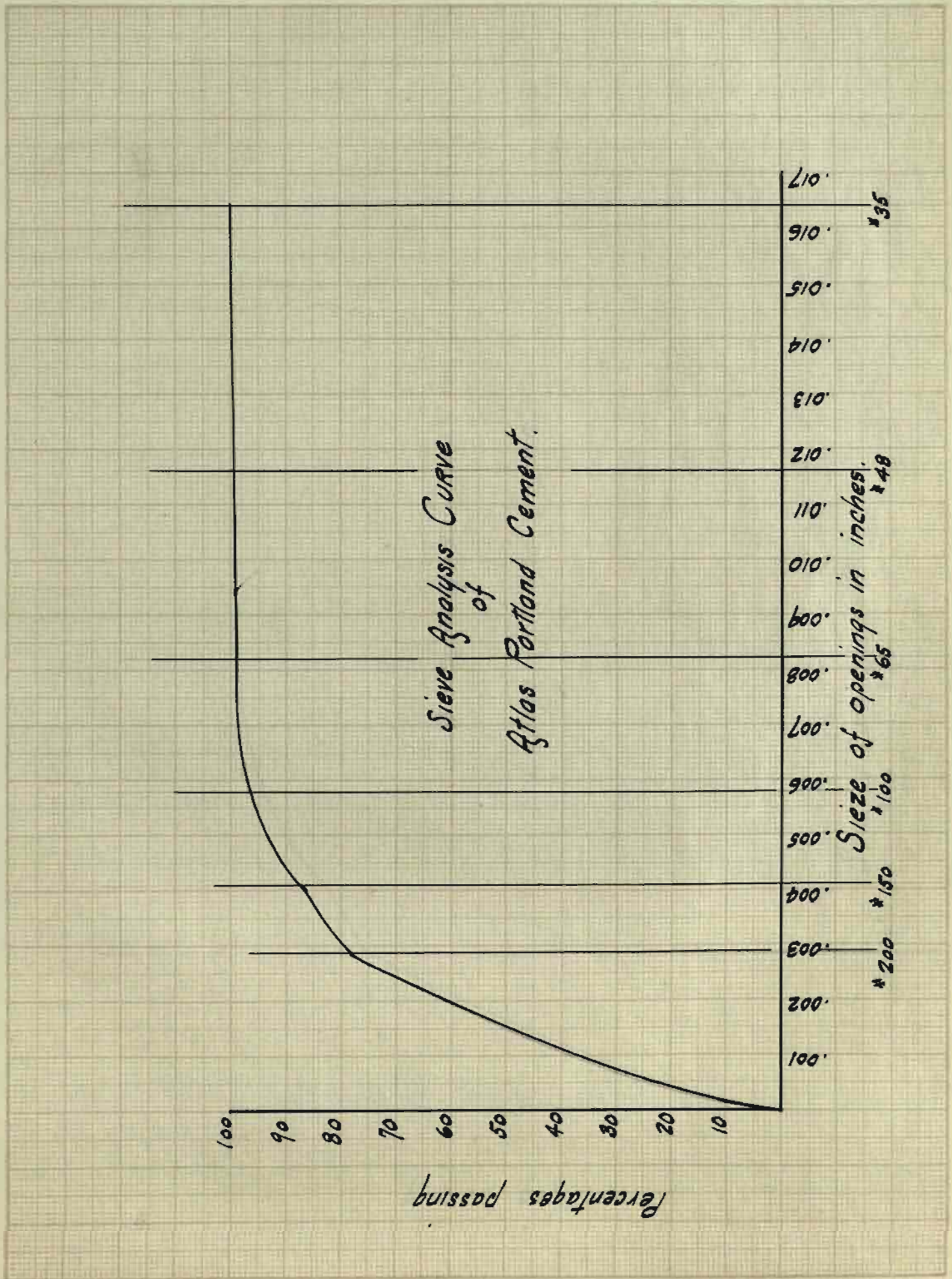
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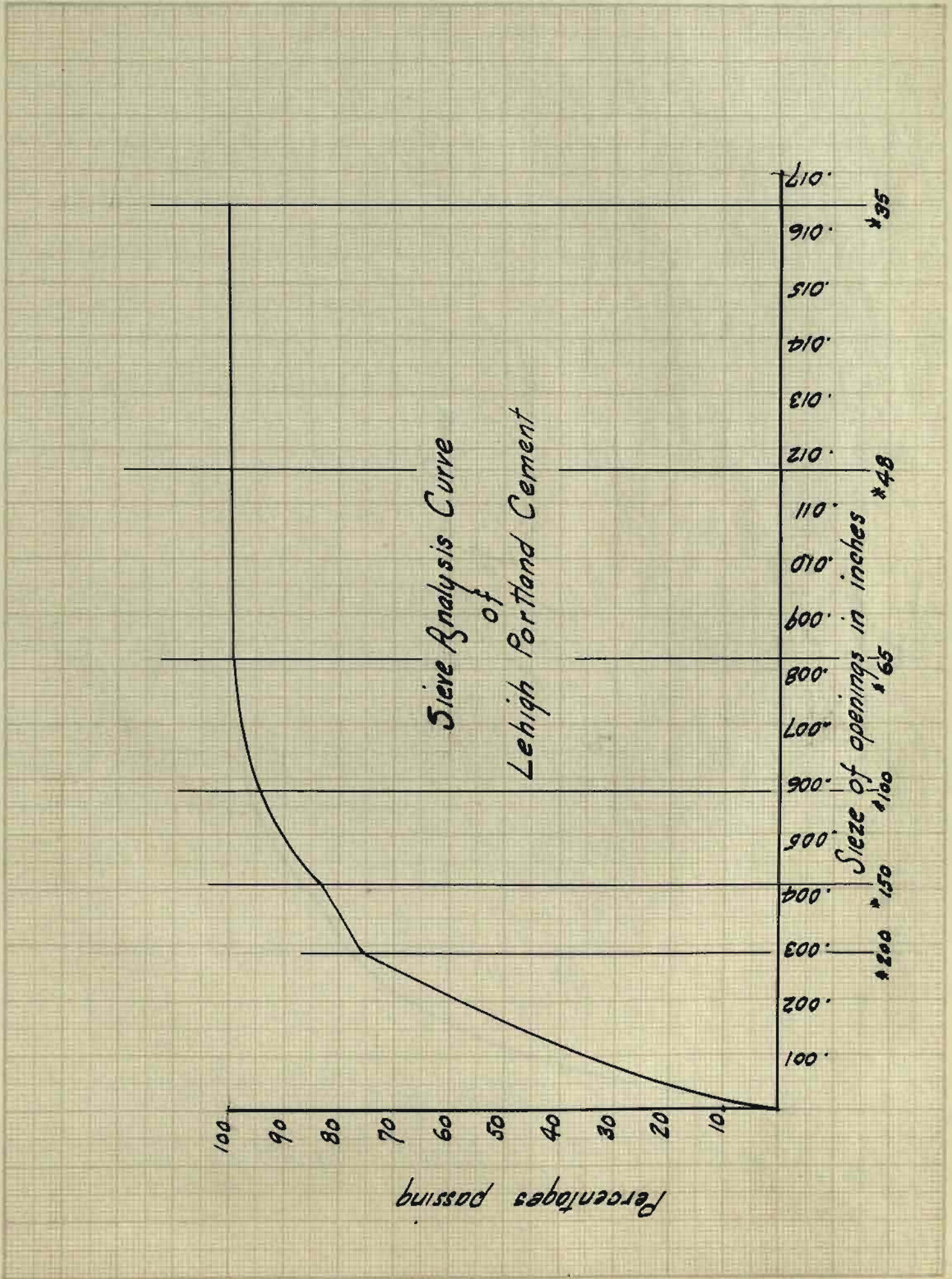
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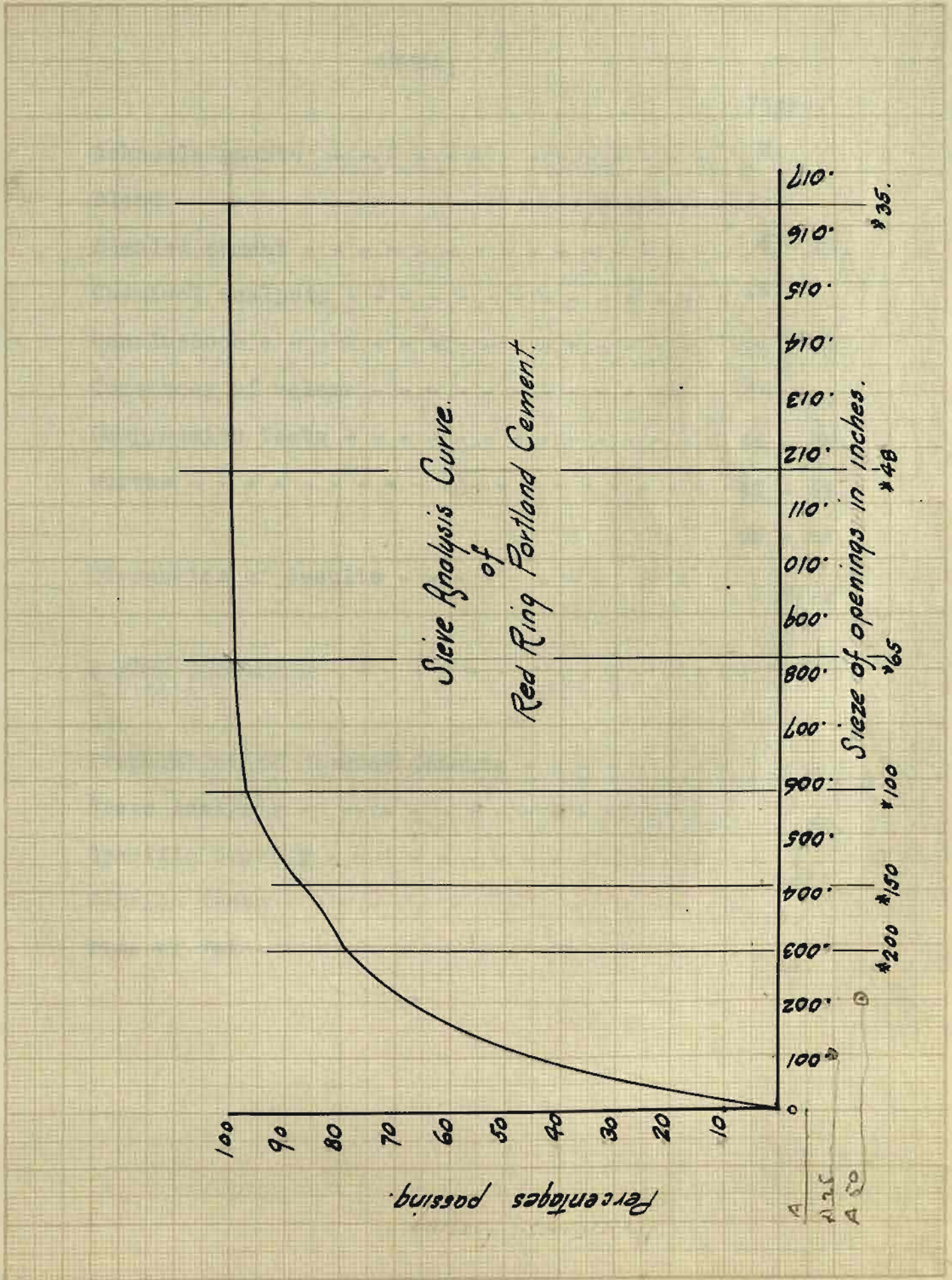
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